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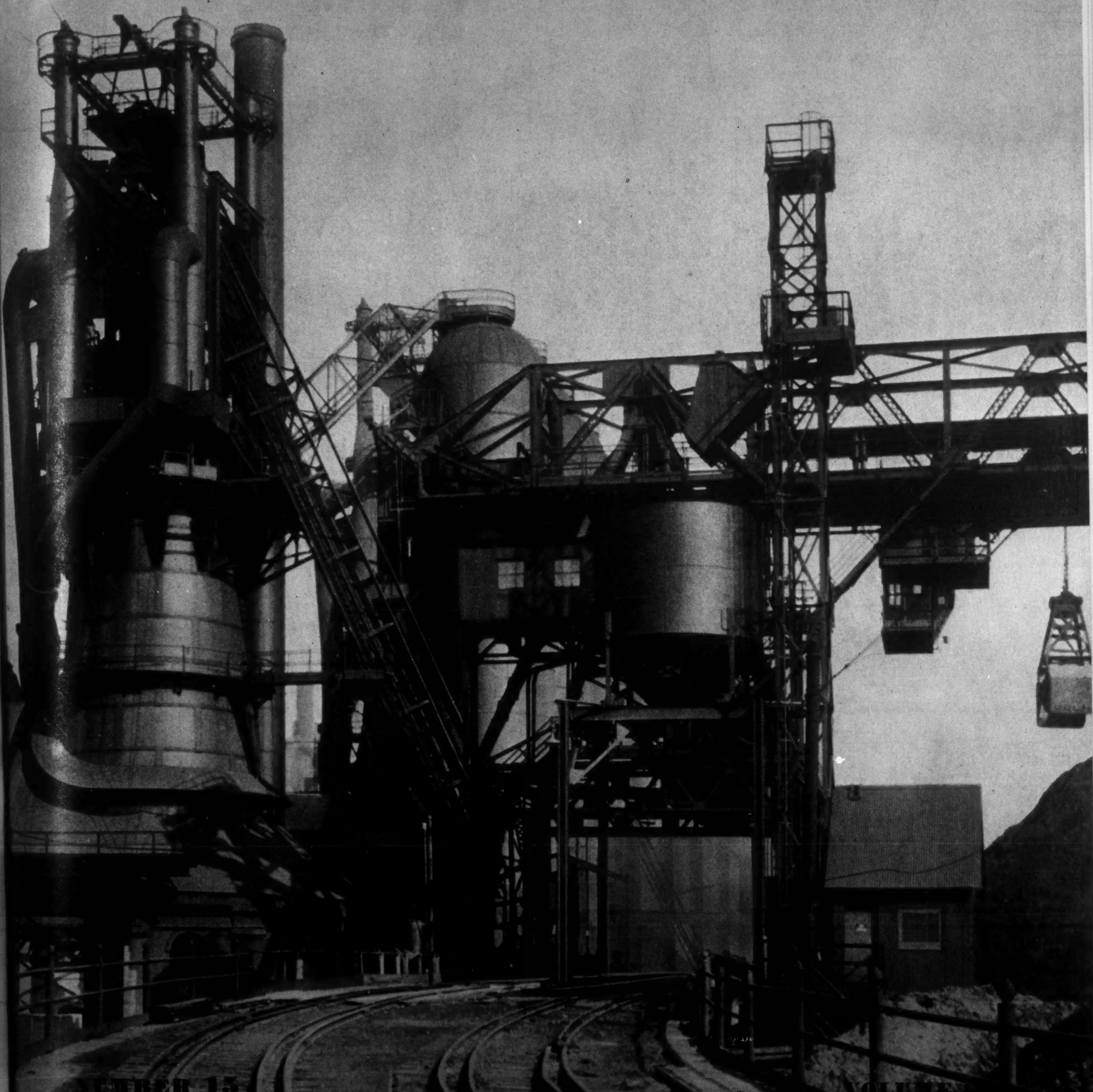

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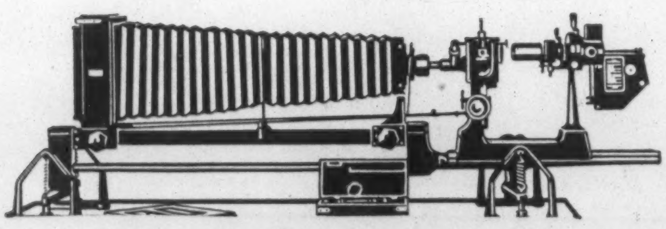

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Published Monthly by
THE CHEMICAL CATALOG COMPANY, INC.

Publication Office: 20th and Northampton Sts., Easton, Pa.
Editorial and Advertising Office: 419 Fourth Ave., New York

BRANCH OFFICES:
953 Leader Building, Cleveland
1050 Straus Building, Chicago
703 Market Street, San Francisco

Francis M. Turner, Pres. *H. Burton Lowe, Vice-Pres.* *R. W. Reinhold, Secy.-Treas.*

VOL. 1 SEPTEMBER, 1930 NO. 15

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Annual Subscription: U. S., Possessions, Mexico and Cuba, $3.00; Canada, $3.50; Other Countries, $4.00; Single copies, 40c.

All communications relating to subscriptions or back issues should be addressed to METALS & ALLOYS, 419 Fourth Avenue, New York.

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Entered as second-class matter July 23, 1929, at the post office at Easton, Pa., under the act of March 3, 1879.

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The Standard for Micro-Metalanalysis

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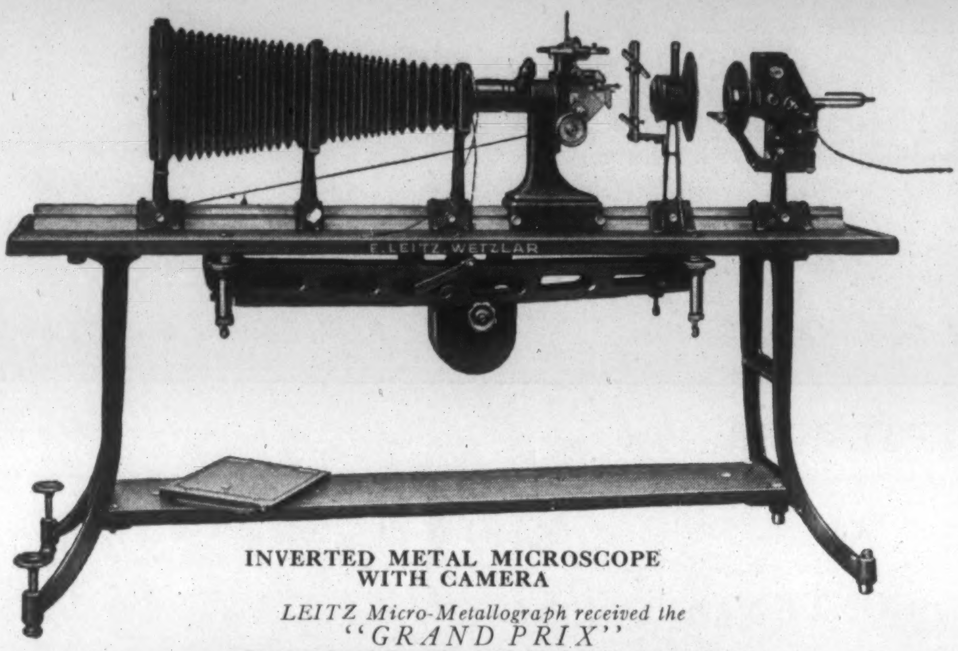

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SHEET STEEL and TIN PLATE

by **R. W. SHANNON**

Associate Member, American Institute of Mining and Metallurgical Engineers

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419 FOURTH AVENUE **NEW YORK, U. S. A.**

PUBLISHER'S PAGE

Note—On this page the publishers will talk right straight to you each month. We will tell you how things are progressing with METALS & ALLOYS. *We will undoubtedly ask your advice on many points. We are publishing this paper not primarily to please ourselves but rather to serve you. And our office door is always open. You are invited to call.*

Ask The Man Who Owns One

In editing METALS & ALLOYS it has become increasingly evident that the most important task of a "journal of scientific metallurgy" is to pass on information on the application of metallurgical science to the metallurgical industries. Or, in other words, to indicate to the reader how he can put science to work making more dollars for his company and himself.

Our readers subscribe to METALS & ALLOYS, because they have found information in it that is of value to them in their business, or because the journal is of such a type that in the course of time, they may reasonably expect to find in it something that does directly bear on some of their own problems. The information may come from the articles, reviews, abstracts, or advertisements. Or, the value may lie in that information, which might otherwise be gleaned from a multitude of other sources, is made available at less expense of the reader's time. Since the readers subscribe in the expectation that in one way or another the subscription will be a good financial investment, the journal should be edited with that idea in view. It has been increasingly evident that the readers want material on scientific metallurgy served up from the point of view of its engineering use, since such articles tend to lead and direct application of the information.

When one wishes to accomplish a certain thing, he can well turn to those who have already done that sort of thing. We are told that to appraise the virtues of a certain motor car we should "ask the man who owns one." Why not, similarly, ask the man who has applied science to practice in the metallurgical field, who has shown the way to apply metallurgical research and metallurgical knowledge so as to make dividends for his own firm, how to steer the editorial policies of METALS & ALLOYS, so as to help the reader to apply metallurgical knowledge to his own practice? Informal suggestions from people of that sort have already been of so much value that it seemed wise to make certain of an unfailing flow of such advice by a rather more formal arrangement.

With that idea in view we have invited a few metallurgists, outstanding in ability and performance in just such lines, to serve as an Editorial Advisory Board, and their names are listed on the title page of this issue. The members of this Board are advisors, not editors. The Editorial Staff is not seeking to shift responsibility onto other shoulders for a bum job, whenever we do a bum job.

The willingness and graciousness with which these busy men accepted our invitation to help is as good proof as we can submit that the basic idea on which METALS & ALLOYS is founded is a sound one. When big and busy men are glad to help the journal toward greater service, it certainly encourages the editorial staff. One of the Board summarizes the attitude of all the members. He says, "I believe that METALS & ALLOYS is serving in a way that no other metallurgical magazine is doing at the present time, and I am interested in helping it become completely successful."

It will be noted that the Board of Editorial Advisors includes some men who have great reputations as theoretical metallurgists, as "high brows," if you will. But any one of them who might be so classed will also, on second thought, be rated as an eminently practical metallurgist, who has put things across from the practical business point of view. It is the man with just that combination of abilities whose advice we need.

The ability of plenty of metallurgists, in university and government circles to put theory into practice, would be on a par with that of the Board, had their environment called for the exercise of that ability. We have not felt it necessary to extend the list of formal advisors to include such men, as it would make the list too long. We know that we have their interest and cooperation. We shall continue to rely on their aid, as in the past.

With such advisors, whether formally listed on the Board or not, active in the endeavor to make METALS & ALLOYS bigger and better, and with a continuance of the helpful comment from the readers, it should be possible to still more nearly approach the ideal with which the journal was started.

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Editorial Comment

In this department I try to comment on metallurgical and allied matters that seem to me interesting and significant. The views expressed reflect my own personal attitude. Many of our readers will have ideas of their own on these subjects and are urged to contribute them in the form of letters which will gladly be published in succeeding issues.—H. W. Gillett, Editorial Director

Psychic Income

One concept grained from a freshman course in Political Economy, has stuck with us through the years, though the rest of the course has long been forgotten. That concept is that a man's total income is made up of various factors besides his cash income, and that the intangible factors which make up his "psychic income" are often of far more importance than the cash.

Up to the minimum that will support a man and his family and allow enough savings and life insurance to prevent actual want to him and his in his old age, one has to look out for cash, more or less irrespective of living and working conditions. Beyond that minimum, increased income may be in the form of extra cash which is used to purchase satisfaction, or it may come in other things than cash; for example, in a job that carries more interest in the job itself during working hours, and in healthy and congenial living conditions for the worker and this family outside working hours.

Many forms of psychic income are not purchasable, since they are incompatible with the requirements of a given job. If one likes to dig in the garden, he must be home now and then to indulge in it, and not spend the bulk of his time in Pullmans and hotels, since we haven't observed that Mr. Statler and his kind have yet planned to make hotel roof gardens available for dirt-digging purposes.

The professor's long vacation, and his sabbatical year, give him opportunity for psychic income of whatever sort he wishes, beside the fact that the intellectual companionship of the college community is psychic income also. Despite the low cash salaries of college professors, we have little fear that their ranks will be greatly depleted. But if a firm does wish to hire a college professor, it should make his conditions of employment such that psychic income is not absent.

Workers in government laboratories are generally underpaid in cash since the promotion system responds but slowly to increases in the cost of living. On the other hand, there is greater security since there is no danger that changes in management or a coalition, like that so common among industrial firms, will result in changes in the technical staff. This, plus short hours, 30 working days vacation, and the pleasure of doing admittedly impartial and thorough scientific work, make up items of psychic income that make the government workers' lot not so bad.

It seems to us that industrial metallurgical jobs do not offer as much in the way of psychic income as do some others, and that metallurgical employers might well give some thought to the matter of increased psychic income to the technical employees.

A merchant, such as a dealer in lumber, or a professional man, such as a dentist, can make up his mind that he wants to live, say, in a town of 125,000 near good duck shooting, and within a day's drive of his wife's relatives, or he can set up any other sort of specifications that appeal to him, with a very good chance of being able to find such a location to settle down in and make a living. He has a rather wide choice of locations that will yield him a good psychic income even though his cash income may not sound affluent.

But the metallurgist must go where the metallurgical industries are, unless he goes into institutional work, such as teaching or research, where he can to some extent select his environment. The industrial metallurgist must often go to a crowded smoky city full of foreign labor, and either bring up his family in surroundings far from healthful, or else waste much time shuttling between his residence and the plant.

The real differential between industrial salaries and salaries in universities, government, laboratories and research institutions is wide in cash wages, but small in psychic income.

One industrial concern that pays good salaries to its metallurgists is, nevertheless, losing them because they are herded into a huge office with hundreds of other workers, surrounded by clacking typewriters, forbidden to smoke, and in general, so located that constructive thought is quite out of the question. They are not allowed to put their desks in the laboratories. Constructive research has come from men working there, but it has been planned at home, not at the plant.

A decent-looking view from one's office window, and clean air to breathe do not diminish one's ability to think. We believe that there would be a growing tendency to locate research laboratories, from which really constructive work, not mere "trouble-shooting" is expected, away from the plants, and even away from the large cities, if the true value of psychic income were better understood. The Dorr Company has the right idea at Westport, where a trout steam runs beside the research laboratory!

Plant metallurgists primarily concerned with production rather than research, cannot often be given much psychic income of location, but their employers could readily increase the psychic income in the job itself with little cash outlay. What are some of the things the technical man prizes? We would mention such things as good apparatus and room to work in, i. e., a laboratory that is not a mere hole-in-a-corner, but one that a visitor can be taken through with pride, and provision of the essential technical and scientific books, journals and periodicals.

Paying a man's technical society dues and his expenses to their meetings as company expense is a good investment. Failing to do it creates a feeling that the company is evading its duty, for every progressive metallurgist knows that he cannot cover his job without being in touch with the literature. When a company freely and gladly pays those expenses, not only for its chief metallurgist, but for the others of its staff who can use the information, the metallurgist feels that the firm is a decent one, and not a short-skate.

We are sure there are many cases where a couple of hundred dollars a year put into the factors that go to make up psychic income, would keep a man satisfied with his employment more effectively than a raise of five hundred.

If more employers and more employees appraised their jobs, present or prospective, from the point of view of psychic income, and took steps to increase it, we believe there would be more satisfied employees and less turn-over.

Readers' Views and Comments

To the Editor of METALS & ALLOYS:

Dear Sir: On page 623 of METALS & ALLOYS, I notice a serious error in the text, in that the Fig. 6 referred to as the "Brackelsberg Furnace" is the "Wuest Furnace," or an entirely different construction. The Brackelsberg Furnace is a revolving air furnace, fired by powdered coal and using the heat of waste gases recuperatively. It is a good furnace because of the use of this waste heat, which differentiates it from the ordinary air furnace with continuous firing by powdered coal.

The furnace gotten up by Prof. Wuest, and advertized under his name, is a stationary combined air furnace and cupola, fired by oil and using the waste heat recuperatively, as shown in Fig. 6 of the text in question. The results obtained with this furnace are irregular, and in the opinion of the writer this is due to the use of oil as the fuel. The enormous amount of water-vapor from the combustion of oil passing over the molten metal in the bath is certain to oxidize the iron and make indifferent or bad heats. Only with a very thick slag cover is there any chance of getting passable results. Should, however, oil be replaced by powdered coal, and either recuperation or regeneration of the heat from the waste gases be practiced, it is the opinion of the writer that the Wuest Furnace will prove to be one of the best so far devised.

Might I suggest that you give a cut of the Brackelsberg Furnace in correction of that of the Wuest Furnace, which was evidently taken from the article abstracted by inadvertence; and also have a short description of the Wuest Furnace, to make the publication of this melting apparatus of some value to your readers.

I want, further, to express my appreciation of your editorial comment on the over-advertizing of furnaces. In reading abstracts of articles on furnaces and processes—particularly recently in connection with the production of high-test cast iron, and on comparing the statements made in such articles with the actual facts as observed in seeing the heats made, one is struck by the "optimism" pervading the statements and the helplessness of the reader in attempting to separate the really good from the purely advertizing features. To read the extravagant claims of wonderful daily heats in one particular make of furnace; to see one of those furnaces in a large foundry condemned as unreliable; and then again to visit the foundry of the plant manufacturing them and putting out the claims, only to find grass growing in the furnace spout, makes one feel inclined to dump a lot of mail unopened into the waste basket.

I have always regretted to see the diversion of young engineering talent into "sales engineering," deeming the unfailing descent from high standards of engineering truth to ordinary commercial methods of sales promotion, to make sales records and resultant pecuniary benefits, an unfair situation for the technical graduate expecting to uphold the standard of ethics of his profession.

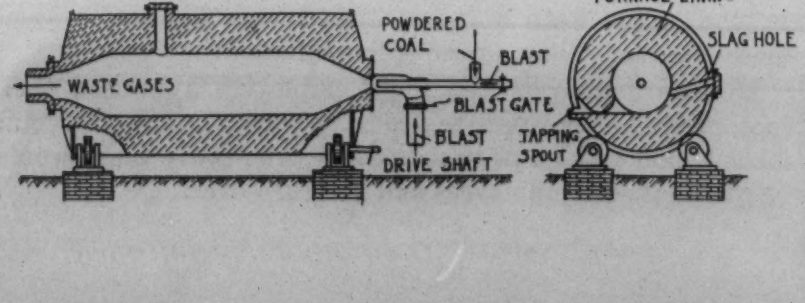
With kindest personal regards, and as Will Rogers would have it—"Yours for the Facts," I remain,

WATCHUNG, N. J. RICHARD MOLDENKE

Correction: Production of High Test Cast Iron

On Page 623 of the July issue of METALS & ALLOYS, Fig. 6 shows a Wuest furnace and not a Brackelsberg furnace as stated in the text. The Brackelsberg furnace consists of a sheet-steel drum mounted on rollers which is provided with a rammed refractory lining (see illustration). The furnace of 6 tons capacity is approx. $16^{1}/_{2}$ ft. long and 4 ft. in diameter inside the lining. The powdered-coal flame enters at one end of the furnace, and the exhaust gases escape through an opening in the middle of the other end which is also used for charging the furnace. The latter is carried out either by hand, or the furnace is raised at the charging end by means of a crane, and the prepared charge is introduced slowly from an elevated chute. The furnace is always freshly charged immediately after tapping the metal or the slag so that most of the furnace heat can be utilized. The rotation of the furnace requires a $^{1}/_{2}$ H. P. motor. During the melting-down the furnace is given a rocking motion; when the melting is completed the furnace is rotated. By the installation of an automatic reversing apparatus the furnace requires no especial attention during the heat.

The melting of 4 tons of malleable iron having a pouring temperature of 1500° C. (2730° F.) requires $2^{3}/_{4}$ hours, and the consumption of about 15% powdered coal of 12–14% ash content; the same amount of gray iron, poured at 1400° C. (2550° F.) require about $2^{1}/_{4}$ hours and about 12% powdered coal; if the iron is charged into the cold furnace, the heat is extended about 30 minutes.



Use of Aluminum in Building Showing Marked Progress

The announcement this week that the new $20,000,000 New England building in Boston would be topped with an aluminum dome and that this metal would be used extensively to obtain special decorative effect, again called attention to the rapid progress being made in its introduction for building purposes. On the Empire Building in New York City, to be the highest in the World, aluminum spandrels were specified, involving a large tonnage of light alloy. Recently the possibility of using aluminum or duralumin structurals in the upper stories of the sky-scrapers was discussed as a means of lightening the supported load throughout the structure. However, the recent progress in the architectural field of aluminum has been most noticeable in its employment for decorative purposes such as symbolic figures, grilles, railings, decorative castings, etc.

Aluminum possesses physical qualities that recommend its use to the architect and engineer in construction of buildings particularly its lightness, facilitating handling and lessening the strain upon the workers while at the same time giving permanence in form and effect.

Personals

Skinner & Sherman, Inc., announce the addition to their staff of Dr. Francis L. Simons as Director of Research. Dr. Simons was formerly a member of this organization, but for the past two and one half years has been Director of Research at the Rogers Fibre Company, Kennebunk, Maine. He is a graduate of Brown University and received his doctor's degree from Yale. He has specialized in organic and physical chemistry and has published several papers on catalysis and the chemistry of colloids.

Dr. Simons' training and experience are such that he brings to the Research Department of Skinner & Sherman, Inc., a very practical viewpoint which is essential in problems of industrial research.

C. B. Woodworth

Walter Smith

C. B. Woodworth, who has been Manager of the Western Division of Vanadium Corporation of America at Chicago, has been appointed Manager of the Railroad Division of the Corporation. His headquarters will continue in the Straus Building, Chicago.

Walter Smith has been appointed Assistant Manager of the Railroad Division of Vanadium Corporation of America. He will also make his headquarters in the Straus Building, Chicago.

Mr. Smith is a graduate in Mechanical Engineering, Cornell University, 1909, and is a member of the American Society of Mechanical Engineers. He entered railway service with the Chicago, Rock Island & Pacific, and subsequently served the Baltimore & Ohio and the Chicago & Northwestern in various supervisory capacities.

In 1916, Mr. Smith entered the service of Pyle-National Company, Chicago, leaving this Company for service in the American Expeditionary Forces, where he was connected with the P. L. & M. Shops and Regimental Camp at Nevers, France. After the Armistice, he was associated with the Inter-Allied Railroad Commission and supervised the transfer of cars and locomotives in Germany in accordance with reparations agreements.

Upon his return to this country, Mr. Smith resumed his service with the Pyle-National Company, with which he was engaged as Special Representative on sales and service work until his association with Vanadium Corporation of America.

Origin and Effect of Inclusions in Steel[†]

A Review

By B. M. Larsen[*]

> *Few users of steel realize how much effort steel-makers are putting on the problem of how to make sounder and cleaner steel. That such effort is applied to alloy and special steels is, of course, well understood by those who use them. That the steel-maker wants to make more reliable plain carbon, tonnage steels is less well appreciated.*
>
> *Through cooperative work with the Bureau of Mines, and in their own laboratories and plants, all progressive steel-makers are patiently studying the question of inclusions, i. e., how to avoid dirty steel. A clear statement of the fundamentals involved is always helpful. This article discusses the essential factors that underlie the whole problem.*

The increased interest in non-metallic inclusions in steel is a natural result of the constantly increasing demand for dependability and uniformity of quality of steels, as a result of their application to more and more severe service conditions. The information available on this general problem is so widely scattered that it seemed desirable to bring it together, and to attempt to evaluate it; to do so is the aim of this review of the present status of the general question of the formation and properties of inclusions in steel. Most of the data included in the literature up to the end of 1929 have been reviewed. As will be seen, the information at hand proves to be rather indefinite and unsatisfactory, in that it raises more questions than it answers; it is obvious, therefore, that some at least of the statements made will require revision in the light of fuller knowledge.

The whole problem of inclusions is a large one, involving lines of investigation such as the following:

(1) Formation: the state of equilibrium between slag and metal bath, each over a range of composition.
(2) Physical properties: melting temperature and phase relations of the several oxides, silicates and sulphides formed by deoxidizing and desulphurizing reactions.
(3) Determination: methods of extraction or separation from the metal matrix.
(4) Identification: by microscopic examination or micro-etching tests of the separated inclusions or of their cut faces in polished steel sections.
(5) The segregation or distribution through the ingot.
(6) Effect on rolling and working properties, and on the mechanical qualities and corrosion resistance of the finished article.

Obviously, if we had full, accurate information on all these phases of the problem, we would have an almost complete physico-chemical basis for the process of steel making. Unfortunately the reliable data now available are meagre, and much remains to be done before we have a satisfactory basis of judgment on many of the specific questions involved. An attempt is made to include such data as seem reliable, to point out where further accurate determinations are requisite, and to outline a rational basis for the interpretation of the results of experimental work on slag-metal equilibria as a means of elucidating the problem of inclusions. In this outline, attention is centered mainly on those inclusions actually formed during various stages in the steel making process, which are in effect only tiny separated portions of the slag phase in a slag-metal system. Inclusions which are more or less accidentally introduced into the metal by erosion of refractories, slags, ore and coke form a case which is subject to the same equilibrium conditions but in which equilibrium is less often approached because of low rates of reaction and diffusion. The paper is written primarily for the chemist and metallurgist familiar with the concept of equilibrium and its implications, for any attempt to reach a still larger group of readers would have made it unduly long.

The subject reviewed in this paper is probably of as much concern to the user as to the maker of steel. The user should know exactly what kind and distribution of non-metallic inclusions he can tolerate without affecting the quality of his particular product, and, in setting up limitations on this point, should see to it that those limitations are not incompatible with the remainder of the specifications. The steel maker should likewise know the kind and distribution of inclusions in his steels, and the possible methods of controlling them within the necessary limits. Apart from this, the problem is important to him because of its intimate connection with the methods of deoxidation and desulphurization in furnace, ladle and mold, and with the whole question of the equilibrium between metal bath and slag and the rates of the several reactions—with what may be called the physical chemistry of steel making.

I. The General Equilibrium Conditions of the Deoxidation Process

A state of *true* equilibrium in the gas–slag–metal system involved in any oxidizing or deoxidizing process used in steelmaking is attained only if there be simultaneously equilibrium

(1) in the (homogeneous) metal phase between deoxidizing element, iron and oxygen or oxides present in solution,
(2) in the slag phase between the several oxides present, including those of iron and of the deoxidizing element,
(3) between metal and slag phases which implies that there be (*a*) a certain distribution between the two phases of the substances (particularly oxides) soluble, and therefore present as such, in both; (*b*) a fixed effective pressure (concentration) of oxygen in the gas phase—that is, in the furnace gases.

Complete equilibrium is not commonly attained in practice because of the relative slowness of some of the processes involved in the completion of the several reactions; we consider it because in no other way can we determine what tends to take place.

Let us now consider the several possible cases, proceeding from the simpler to the more complex.

Case 1. Pure iron is melted in a small closed chamber containing oxygen. The oxygen will dissolve in and react with the melt until the oxygen pressure of the gas phase and that of the solution have become equal. As more oxygen is introduced, the FeO content of the metal increases until it reaches saturation (which at 1530° C. will correspond to 0.21% oxygen).

Case 2. At this point FeO, or a liquid solution of Fe in FeO, will begin to separate to form a slag phase, the metal phase remaining at the same FeO content, with a given constant temperature. If we assume that all the oxygen in the

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[†] In three parts, Part I; Part II will be published in October, Part III will be published in November.

[*] Research Laboratory, United States Steel Corporation, Kearny, N. J.

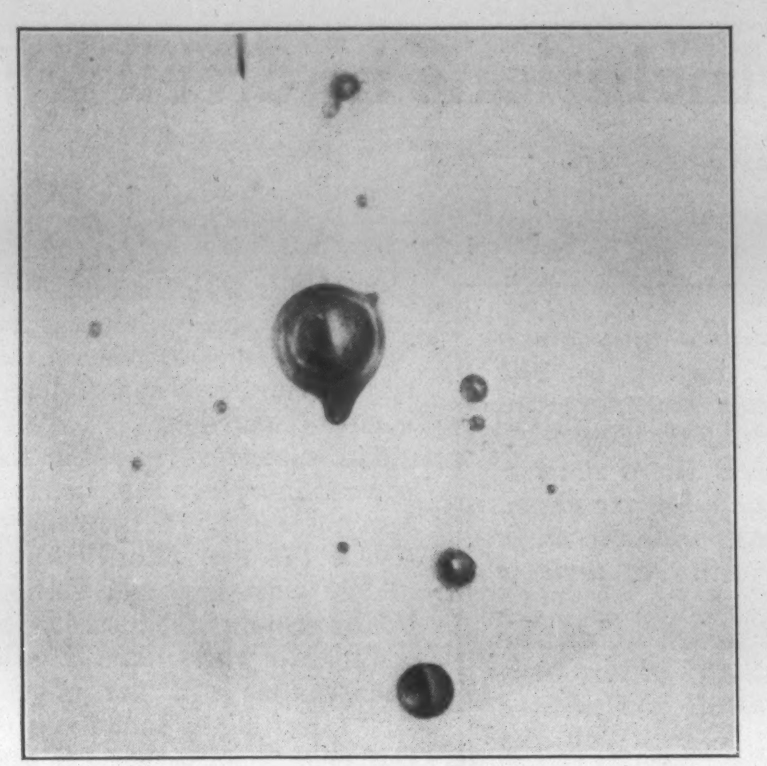

Fig. 1—Silica Inclusions in Cast Low Carbon Steel. Mag. 300 ×. *(Metallurgical Division, Pittsburgh Station, U. S. Bureau of Mines, Pittsburgh, Pa.)*

metal is present as FeO (or dissociated oxygen), then the reaction

$$Fe_3O_4 + Fe \longrightarrow 4FeO \qquad (1)$$

should go practically to completion in the presence of excess iron and the slag phase at equilibrium should consist of FeO (saturated with dissolved iron). The oxygen pressure of all phases is then very low (below that attainable in any vacuum furnace) and is essentially equal to the dissociation pressure of FeO, at the given temperature. The dissociation pressure of FeO may be approximately calculated from the results given by Eastman on the equilibrium in the Fe–O–H_2 system[1] and the dissociation pressure of water vapor.[2] This gives a value of 3.7×10^{-8} atmospheres at 1600° C., which it must be remembered is only a fairly good approximation. The addition of pure iron will lower the FeO content of the metal phase and cause it to absorb a small amount of FeO from the slag. The addition of FeO makes practically no change except a slight absorption of Fe from metal into slag phase. If more oxygen is introduced, the oxygen pressure of the gas phase will then be above that of FeO (saturated with Fe) and the reaction

$$3FeO + {}^1/_2O_2 \longrightarrow FeO{\cdot}Fe_2O_3 \qquad (2)$$

will occur; but as this Fe_2O_3 formed at the slag-gas interface dissolves in the slag it diffuses down to the slag-metal interface and is reduced to FeO by reaction (1), so that as long as the metal phase is present, no measurable amount of Fe_2O_3 should presumably be present in the slag at equilibrium.

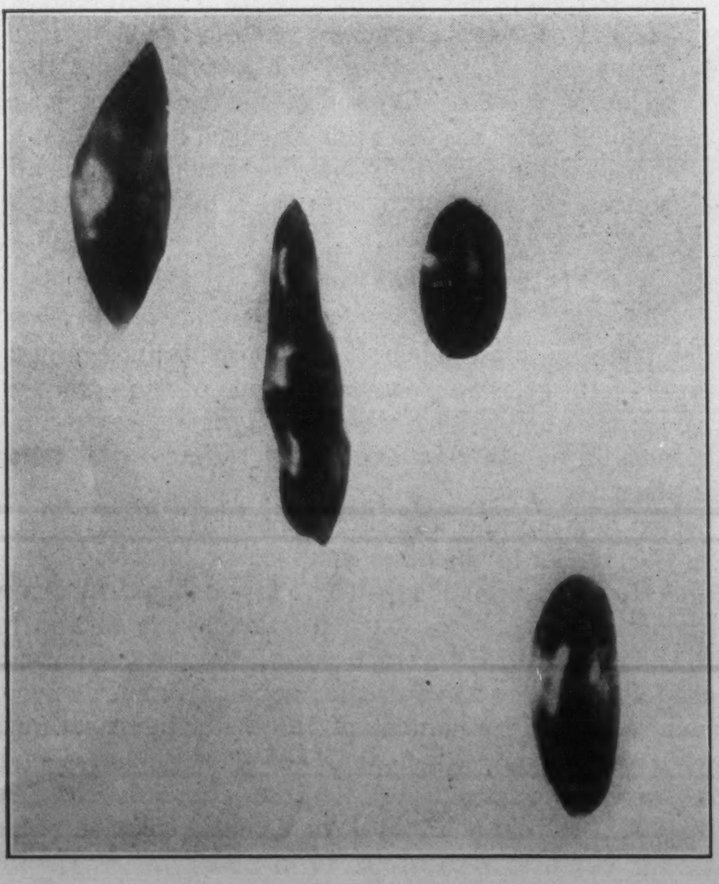

Fig. 2—Elongated Silica Particles in Forged Low Carbon Steel. Mag. 500×. *(Metallurgical Division, Pittsburgh Station, U. S. Bureau of Mines, Pittsburgh, Pa.)*

Case 3. With metal and slag phases both present, the slag will now be almost pure FeO and the metal will be iron saturated with FeO. If we assume the chamber to be perfectly tight, and the material of the crucible walls to have zero oxygen pressure, the gas phase will consist mainly of oxygen and iron vapor, both at extremely low pressures, and the escaping tendency or oxygen pressure of all three phases will be equal to that of liquid FeO saturated with iron. We may now introduce into the slag some oxide such as CaO or MgO which has a very small oxygen pressure even at high temperature; it has some slight solubility in iron and so saturates the metal with CaO or MgO which reacts with Fe to form a trace of metallic Ca or Mg in solution. However, with steel-making temperatures (1500–1600° C.) so far below the normal melting points of these oxides, it is probably safe to assume that their dissociation pressures are negligible in comparison to that of FeO and they may, therefore, be regarded simply as diluents in the slag. If MgO, for example, is introduced into the slag, the FeO is diluted, and the oxygen pressure of the slag phase proportionately decreased; FeO will then be absorbed from the metal into the slag until the escaping tendency of oxygen in the metal phase is again equal to the lowered value for the slag phase. We thus have FeO "distributed" in equilibrium between metal and slag, and some sort of "distribution law" will govern this division. If such MgO-FeO mixture may be regarded as an ideal solution, and if the FeO in the metal phase is almost entirely undissociated, then the simple distribution law applies. The concentration of FeO in the metal will then be equal to its saturation value under a pure FeO slag, multiplied by the molecular concentration of FeO in the slag phase.

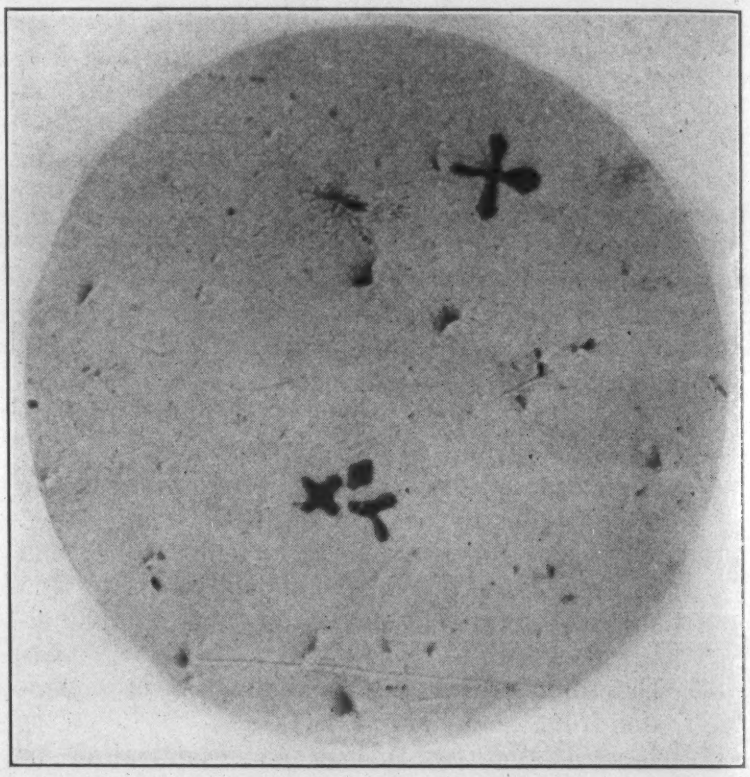

Fig. 3—Manganese Oxide Particles in Cast Low Carbon Steel. Mag. 500×. *(Metallurgical Division, Pittsburgh Station, U. S. Bureau of Mines, Pittsburgh, Pa.)*

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[1] Eastman, E. D., & Evans, R. M., Equilibria Involving Oxides of Iron. *Journal American Chemical Society*, Vol. 46 (1924), pages 888–903.

[2] Eastman, E. D., The Free Energy of Water, Carbon Monoxide and Carbon Dioxide. *Information Circular* No. 6125, *Bureau of Mines*, May 1929.

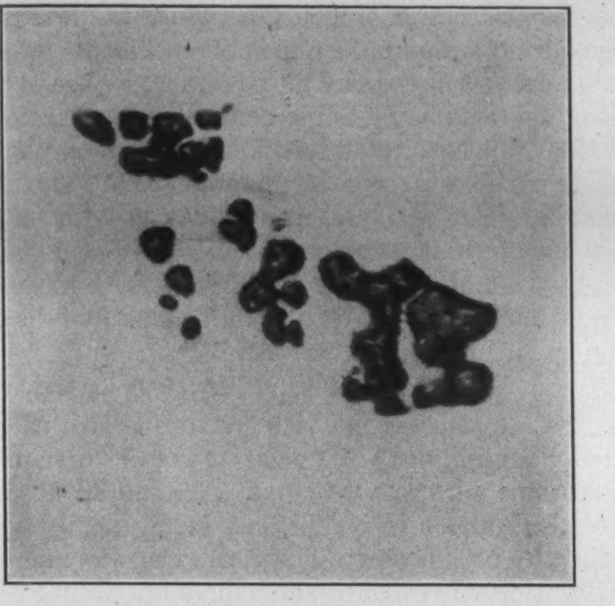

Fig. 4—Aluminum Silicate Inclusion in Cast Steel. Mag. 500×. *(Metallurgical Division, Pittsburgh Station, U. S. Bureau of Mines, Pittsburgh, Pa.)*

The systems MgO–FeO and CaO–FeO have not been studied, but they probably form simple eutectiferous series. Liquid mixtures of such oxides may approximate ideal solution behavior. The results of Herty and Gaines[3] indicate that in the system CaO–FeO–Fe, these assumptions are justified, though the actual data are sufficiently inconsistent so that moderate deviations from ideal solution behavior would not be noticeable.

As to the lack of appreciable dissociation of FeO in the iron solution, it is difficult to decide in how far this assumption is justified. The oxygen pressure of the gas phase at equilibrium is extremely low, the maximum value being the dissociation pressure of FeO. The concentration of O_2 molecules in the iron must, therefore, be inappreciable. The FeO in solution will perhaps tend to dissociate as follows:

$$\mathrm{FeO} \rightleftarrows (\mathrm{Fe}^{+}) + (\mathrm{O}^{-}) \qquad (3)$$

but since iron is both the solvent and one of the products of the reaction, it seems probable that the amount of dissociation is small, and that most of the dissolved oxygen is present as FeO. In what follows we shall assume that oxygen is present in steel entirely in the form of dissolved FeO, MnO, CO, etc., or as suspended particles of the various oxides.

We may thus plausibly assume that the addition to the FeO slag of CaO, MgO and similar oxides which do not tend to form stable compounds with FeO, will simply lower the oxygen pressure of the slag in proportion to the mol fraction of the oxide added. On the basis of Herty's[3] value of 0.30% oxygen (or 1.35% FeO) dissolved in iron under a pure FeO slag at 1600° C. then under a MgO-FeO slag with the mol fraction of MgO = 0.5 (36% MgO, 64% FeO), just half as much (0.68%) FeO dissolved in the iron would be in equilibrium with the slag phase. By progressive dilution of this slag phase with a slag mix such as CaO and Al_2O_3 which would remain liquid at 1600° C., the FeO concentration in the metal phase should be progressively lowered; and as the FeO content in the slag approaches zero, the metal phase should become almost completely deoxidized by a simple extraction process which should introduce unmeasurable traces of other metals into the iron. This process is identical in principle with the familiar extraction of organic substances from solution in water by the use of an organic solvent such as ether.

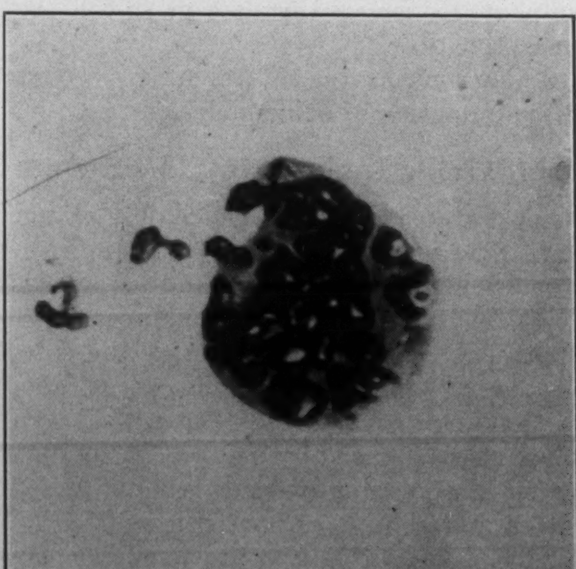

Fig. 5—Inclusion Consists of Aluminum Silicate with Excess Silica. Mag. 500×. *(Metallurgical Division, Pittsburgh Station, U. S. Bureau of Mines, Pittsburgh, Pa.)*

Case 4. In the preceding case, the assumption was made that the oxides employed to dilute the FeO slag have no measurable solubility in iron and are not appreciably reduced by iron at steel-making temperatures. If, however, a more readily reducible oxide, such as MnO, is added to a pure FeO slag phase over iron, the equilibria involved become somewhat more complex. The first effect is mainly the dilution of the slag, lowering its oxygen pressure, so that more FeO is absorbed from the metal. MnO, however, seems to be slightly soluble in iron and is also reduced by pure iron, so that as the MnO content in the slag increases, a small amount of MnO is absorbed into the metal phase where it reacts with iron,

$$\mathrm{MnO} + \mathrm{Fe} \rightleftarrows \mathrm{FeO} + \mathrm{Mn} \qquad (4)$$

to form manganese in solution. This continues until equilibrium concentrations of manganese, MnO and FeO are present. If metallic manganese is now added, this practically all dissolves in the metal phase where it upsets the equilibrium, and reacts with FeO to form MnO, which is partly absorbed into the slag phase. If FeO is added to the slag, MnO will tend to pass from metal to slag, FeO will be absorbed by the metal and will react with Mn to form additional MnO.

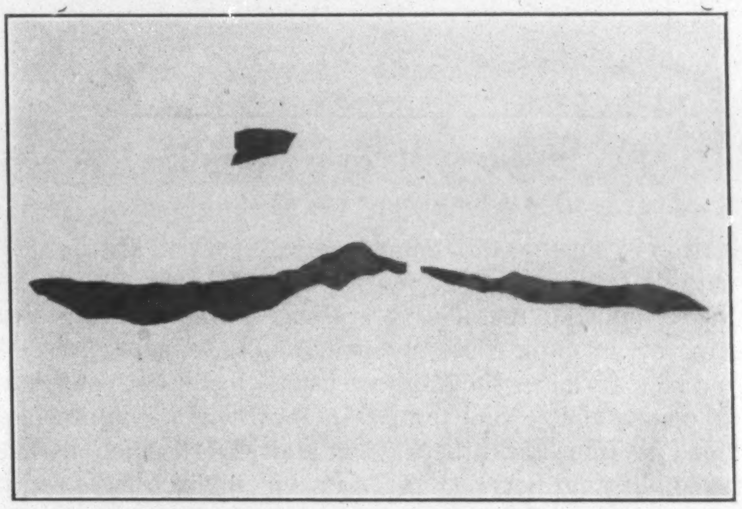

Fig. 6—Elongated Ferrous Silicate in Forged Steel. Mag. 250×. *(Metallurgical Division, Pittsburgh Station, U. S. Bureau of Mines, Pittsburgh, Pa.)*

Systems of this type with iron and oxygen are formed by silicon and chromium, and probably also by vanadium, titanium and other metals. Zirconium and aluminum are probably intermediate between these and calcium and magnesium, being reduced in perhaps barely measurable amounts by pure iron at steelmaking temperatures. In all cases, there must ultimately be (1) equilibrium between each metal and its oxide in the homogeneous metal phase, (2) a distribution equilibrium between metal and slag for each of the metal oxides present, and (3) equality in total oxygen pressure between the slag and the metal phases, so that each of these may be in equilibrium with the gas phase.

Case 5. If the deoxidizing element or the deoxidation product is a gas, the same general conditions govern, except that the slag phase may be absent; this case includes de-

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[3] Herty, C. H., Jr., & Gaines, J. M., The Solubility of Iron Oxide in Iron. *Cooperative Bulletin* 34, *Mining & Metallurgical Advisory Boards*, Pittsburgh, Pa. (1927).

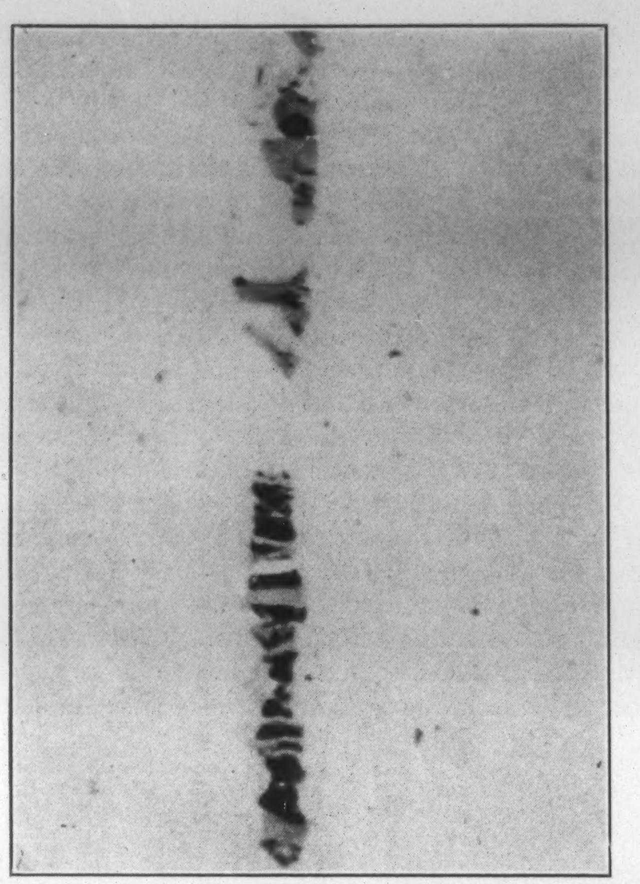

Fig. 7—Elongated Manganese Silicate in Wire. Mag. 500×. (*Metallurgical Division, Pittsburgh Station, U. S. Bureau of Mines, Pittsburgh, Pa.*)

oxidation by means of carbon or hydrogen which are discussed in detail later.

Nearly all the metal-slag systems formed during steelmaking or finishing come under one of these categories. In actual steel furnaces the slags are usually complex, containing both oxides (FeO, SiO_2 and MnO) which are appreciably reduced by iron, and others (CaO and MgO) which are not. True equilibrium between gas, slag and metal phases can be attained only in a furnace from which the air is excluded since the oxygen pressure of any metal-slag system containing metallic iron is extremely low. The composition of the metal phase, however, is determined primarily by the reactions at the slag-metal interface, which, especially when the metal is well covered by a layer of fairly quiet slag, are so rapid compared to the slow rate of diffusion of oxygen, Fe_3O_4 or Fe_2O_3, through the slag, that a close approach to equilibrium between slag and metal may well exist independently of the proportion of oxygen in the furnace gases.

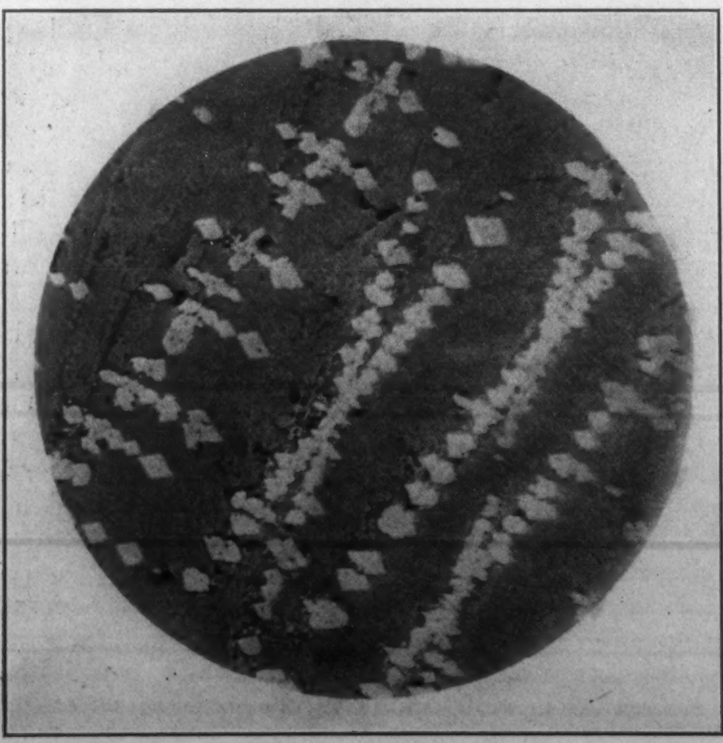

Fig. 8—Fayalite in Ferrous Silicate. Mag. 250×. (*Metallurgical Division, Pittsburgh Station, U. S. Bureau of Mines, Pittsburgh, Pa.*)

In any consideration of inclusions which result from the use of a deoxidizer, it should be remembered that they are simply separate particles of the slag phase formed by the deoxidation reactions, this slag being formed entirely by separation of the oxides from supersaturated solution in the metal phase. The first oxide particles to separate may not be of the equilibrium composition. For example, in deoxidation with manganese, suppose enough manganese is added to give at equilibrium a metal phase which will be in equilibrium with a slag of 50% MnO and 50% FeO. After the manganese is added to the solution of FeO in Fe, the reaction

$$Mn + FeO \rightleftarrows MnO + Fe \qquad (5)$$

occurs, the solution becomes supersaturated with MnO, and particles of nearly pure MnO separate first. These will not be in equilibrium with the iron but will tend to absorb FeO, the rate of approach to equilibrium being largely dependent upon the rates of diffusion of FeO in the slag and metal phases. Rapid diffusion is favored by the high temperatures prevailing and by the fact that the particles of slag are finely disseminated throughout the metal. When the inclusions as formed are liquid, equilibrium is probably approached fairly closely even in the few minutes interval between the additions of deoxidant and the pouring of the steel into the molds.

Distribution of Oxides or Sulphides between Slag and Metal Phases

In liquid metal-slag systems it often happens that an oxide or sulphide component is completely miscible with the slag but has only a small solubility in the liquid metal. Suppose the slag consists of two oxides (or two sulphides) A and B, which are completely miscible with one another but each only slightly soluble in the metal. If we make the plausible assumption that such a slag would be an ideal solution—which probably is approximately true for many of the common mixtures, such as CaS-FeS, FeS-MnS, CaO-MgO, CaO-FeO-MnO, etc.—the respective concentrations in the metal phase are, according to the simple distribution law, as follows, for a given temperature: if x denotes maximum solubility of A in metal under a slag composed of pure A, and N_A the mol fraction of A in the actual slag, and y and N_B are the corresponding quantities for B, then M, the total molecular concentration of A and B in the metal becomes

$$M = N_A x + N_B y \qquad (6)$$

At present, almost no data are available on slag-metal equilibria which are accurate enough to afford a test of the validity of such assumptions as are involved in this formula. Such tests should be very valuable in understanding furnace reactions. It is very difficult to distinguish, for example, between sulphur present as FeS or MnS, or oxygen present as FeO, MnO or SiO_2 in steel samples, although determinations of *total* sulphur, oxygen, manganese or silicon can be made with comparative ease.

We shall now consider the several systems commonly concerned in the formation of oxide inclusions.

II. Iron Oxide Inclusions: The System Fe–O

The simplest system is that in which only oxygen and iron are present. The system Fe–O has been studied by Tritton and Hanson,[4] Schönert[5] and Herty[3] and his associates. The part of the system important in steel making is shown in Fig. 9. The solubility of FeO in liquid iron at the eutectic point (1520° C.) seems fairly well established at about 0.94% FeO, corresponding to 0.21% O_2. The critical points in iron are not appreciably changed by the presence of oxygen which indicates that the amount of oxide soluble in solid iron is small; Tritton and Hanson estimated it as 0.05%, Wimmer[6] as about 0.035% O_2. No data are available, however, to

[4] Tritton, F. S., & Hanson, D. J., Iron and Oxygen. *Journal Iron & Steel Institute*, Vol. 110 (1924), pages 85–143.

[5] Schönert, K., Beitrag zum System Kohlen-Eisen-Sauerstoff. *Zeitschrift anorganische und allgemeine Chemie*, Vol. 154 (1926), pages 220–225.

[6] Wimmer, A., Ueber den Einfluss des Sauerstoffs auf die physikalischen und technischen Eigenschaften des Flusseisens. *Stahl und Eisen*, Vol. 45 (1925), pages 73–79.

indicate whether these values apply to solid iron at ordinary temperature or near its melting point. From the appearance of FeO inclusions in iron-oxygen alloys cooled rapidly from the molten state, and from the lack of effect on the critical points, the present writer is inclined to think that there is, as is usual, a sudden drop in solubility at the freezing point, the solid metal containing around 0.05% O_2 or less in solid solution, and that this solubility presumably decreases during cooling to ordinary temperatures, as indicated by dotted lines in Fig. 9. The solubility in liquid iron increases rapidly above the melting point as indicated by line BC taken from the data of Herty[3] for iron melted under a pure FeO slag.

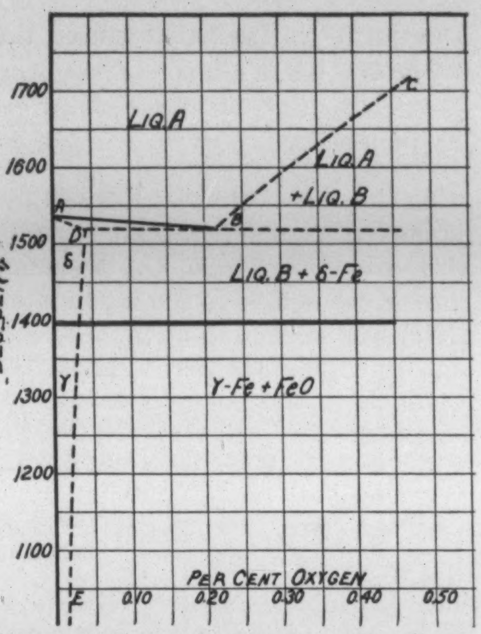

Fig. 9—Tentative Sketch of the Iron-rich Portion of the Fe-FeO Equilibrium Diagram

Pure FeO inclusions are formed only in systems from which all oxides (such as MnO, SiO_2, Cr_2O_3, TiO_2 and V_2O_3) which are appreciably reduced by contact with liquid iron are absent. Such oxides as CaO, MgO, BaO, Na_2O, when added to the FeO slag are so nearly insoluble in the metal phase and so little reduced by the metal that the inclusions found in the solidified metal are still practically pure FeO. The only effect in this case is to dilute the slag and reduce its oxygen pressure so that part of the FeO in the metal is "fluxed out" or extracted from the iron into the slag, leaving a smaller amount to form FeO inclusions in the solidified metal. As indicated above, such slag mixtures may approximate to an ideal solution; the degree of departure from ideal behavior is not known, although Herty's[3] results indicate that in the case of CaO-FeO mixtures the divergence is small. On this basis, for iron in contact with a slag composed of FeO with MgO, CaO or Na_2O, the amount of FeO in the metal phase at any given temperature between 1520 and 1700° C. may be approximated fairly closely by multiplying the value taken from the curve BC (Fig. 9), by the mol fraction of FeO in the slag. Even in the case of a basic open-hearth slag high in CaO and MgO and low in MnO and Al_2O_3, such a calculation should give a fair approximation, when the carbon content in the metal is down to around 0.15% or less, or when all reactions of carbon, silicon and manganese with FeO in the metal have approached equilibrium.

In pure iron-oxygen alloys the only inclusions which can be visually identified with a microscope are tiny, light gray globules, probably composed of FeO saturated with iron and distributed uniformly throughout the metal. They are attacked slowly (mostly by pitting around the edges) by most acid etching reagents, and are reduced to metal by heating a polished surface in hydrogen at 600–900° C., leaving tiny black pits instead of the original light gray surfaces.

These inclusions cannot be eliminated from the molten metal by rising to the surface since they separate from solution only during freezing or the subsequent cooling of the solid metal. They do not ordinarily occur in commercial steels, except in small amounts in certain low-carbon steels which are very low in silicon and in manganese content, and in variable amounts in Armco iron. In all steels with FeO inclusions, the ferrite crystals are presumably saturated with FeO in solid solution. Certain effects of the presence of FeO on case-carburized structures[7, 8, 9] and certain aging effects on cold drawn wire[10] seem to indicate that the true solubility of FeO in iron at ordinary temperatures is very low, perhaps of the order of 0.005–0.010% O_2, and that submicroscopic particles of FeO are formed, due to the decrease in its solubility in the solid metal with decreasing temperature. No method has been devised to indicate directly the presence of such submicroscopic particles, and yet the suspicion of their presence in oxidized metal has persisted ever since they were rather vaguely suggested by Ehn[7] in his paper on abnormal steels in 1922. It is suggested, for example, that in a hypereutectoid steel the normal structure of cementite network around grains of lamellar pearlite is dependent upon a certain degree of supercooling below the critical points Ar_3 and Ar_1. Submicroscopic FeO particles may prevent such supercooling by providing nuclei for the separation of carbide from solution and thus facilitate the separation into the massive cementite and ferrite grains characteristic of the so-called abnormal steels.

Pfeil[10] found that very pure iron showed no aging effects after cold work, but that if very small amounts of either carbon or oxygen were present, an increase in tensile strength of 2000–3000 lbs./in.^{2} was obtained on aging for one month. Such a change is usually associated with the presence of tiny particles of a harder phase separating from solid solution, in this case tiny particles of Fe_3C or FeO. The conditions suggest that on cooling a lowering of solid solubility causes the metal to be supersaturated with respect to carbide or oxide, and that cold-working favors the approach to equilibrium by precipitation of the excess carbide or oxide. The solubility lines as drawn in Fig. 9 are at least in qualitative agreement with these results, but more data are obviously necessary to determine the solubility of FeO in solid iron.

Wimmer[6] added varying amounts of oxygen (0.03–0.20%) to steel containing 0.05% C, 0.38% Mn, 0.045% P, 0.035% S and a trace of silicon, and measured the physical properties and working qualities of the resultant alloys. His results

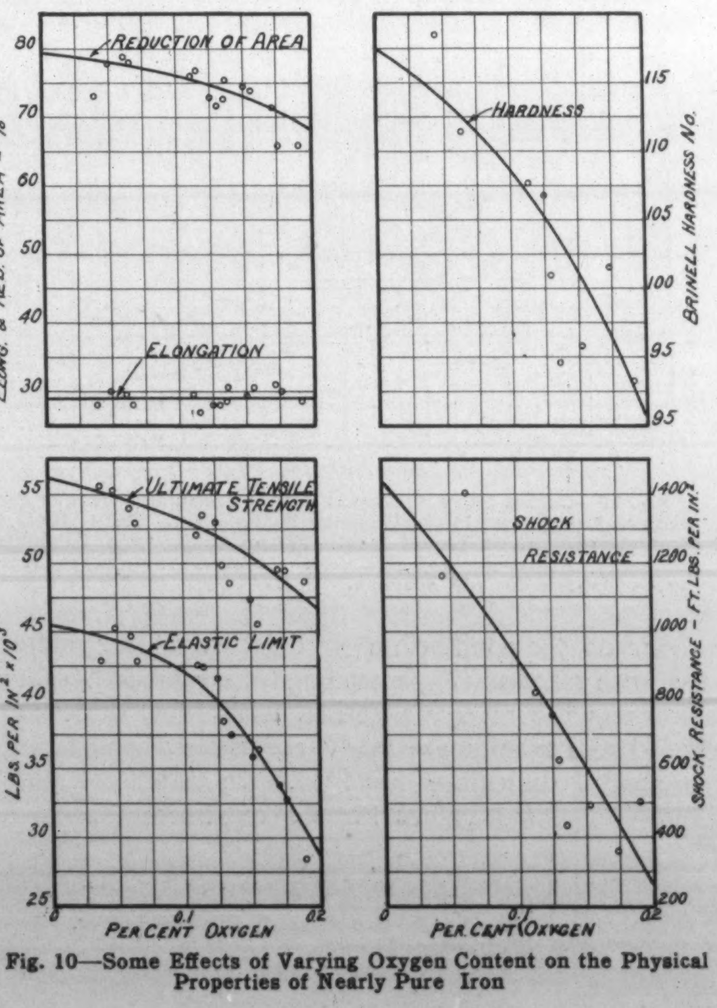

Fig. 10—Some Effects of Varying Oxygen Content on the Physical Properties of Nearly Pure Iron

are reproduced in Fig. 10. The carbon and manganese contents decreased from 0.06% C, 0.38% Mn with 0.038% O_2, to 0.03% C, 0.24% Mn with 0.192% O_2, while the average grain size increased from about 680 to 27,500 $\mu\mu$. The changes in hardness and tensile strength may in large measure be connected with these differences in analysis and grain size, but the large and steady decrease in shock resistance must be, at least partly, caused by the increasing number of tiny FeO inclusions. It should be of fundamental importance to make a similar study of a series of pure iron-oxygen alloys, with oxygen content varying over this same range, and including one or two melts of extremely low FeO content. In such a study, the melts should be large enough (perhaps 15–20 lbs. each) to afford sufficient material for a comprehensive series of tests. Ever since the invention of the Bessemer process, when so much trouble was encountered in making steel that could be hammered and rolled, and this was overcome by the addition of ferromanganese and spiegel, all sorts of bad effects have been attributed to oxygen in steel or iron. Whether these are due to the presence of FeO inclusions, oxygen in solid solution, gases evolved during freezing, presence of FeS, absence of manganese or silicon in solution, etc., has never been satisfactorily determined; a careful study of really pure iron-oxygen alloys should help to clear up the matter.

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[7] Ehn, E. W., Influence of Dissolved Oxides on Carburising and Hardening Qualities of Steel. *Journal Iron & Steel Institute*, Vol. 105 (1922), page 157.

[8] Epstein, S., & Rawdon, H. S., Steel for Case-hardening—Normal and Abnormal Steel. *Research Paper* No. 14, *Bureau of Standards Journal of Research*, Sept. 1928.

[9] Herty, C. H., Jr., & Larsen, B. M., Abnormality in Case-Carburized Steels. *Cooperative Bulletin* 45, *Mining & Metallurgical Advisory Boards*, Pittsburgh, Pa. (1929).

[10] Pfeil, L. B., The Change in Tensile Strength Due to Aging of Cold-drawn Iron and Steel. *Journal Iron & Steel Institute*, Vol. 118 (1928), pages 167–194.

III. Deoxidation with Manganese: MnO–FeO Inclusions

If manganese is added to a system composed of a pure FeO slag over iron saturated with FeO, the reaction

$$Mn + FeO \rightleftarrows MnO + Fe \qquad (7)$$

occurs in the metal phase. Part of the MnO formed passes into the slag, and the reaction tends to continue until complete equilibrium has been attained, as outlined previously.

Oberhoffer and Schenck[11] made equilibrium measurements in this system. Iron and iron oxide were melted together in a magnesia crucible in an Arsem type vacuum furnace, and MnO or manganese metal added to the melt. After 3–5 minutes at 1600° the furnace was quickly cooled, and the solidified metal was analyzed for total oxygen and manganese. Fig. 11 shows the results of these determinations, the circles representing the equilibrium obtained by adding manganese metal, with reaction (7) proceeding from right to left, and the black spots the reverse reaction, with MnO added to the melt. These results are fairly consistent, considering the experimental difficulties involved. LeChatelier[12] and McCance[13] calculated values for the equilibrium constant of equation (7). LeChatelier used the Clapeyron equation in the form

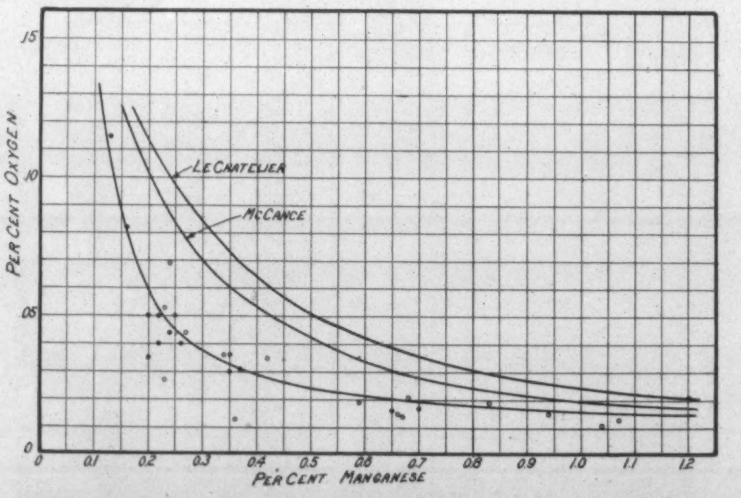

Fig. 11—Curves Showing Residual Manganese and Oxygen Contents at Equilibrium in the Reaction FeO + Mn. Fe + MnO, at Around 1600° C. in Liquid Iron. Upper Curves from Calculated Values by LeChatelier and McCance. Lower Curve—Experimental Data of Oberhoffer and Schenck.

$$ln\,p = -\frac{\Delta H}{RT} + I \qquad (8)$$

using the value 0.032 for I (given by Matignon as valid for a number of similar systems) to find the oxygen pressures of MnO and FeO at 1600° C. Assuming that the slag phase was pure MnO and that the amount of oxygen as MnO in the metal was negligible in proportion to that present as FeO, and using the fact that a saturated solution of FeO in iron should have the same dissociation pressure as pure FeO, he computed the upper curve in Fig. 11.

The true equilibrium expression for reaction (7) is

$$K_{(7)} = \frac{(a_{MnO})(a_{Fe})}{(a_{Mn})(a_{FeO})}$$

Since LeChatelier assumed that the slag phase was pure MnO, the concentration of MnO in the metal became constant and this term could be omitted. The concentration of iron, the solvent, remains essentially constant over the range of oxygen and manganese contents present in ordinary commercial steels, and its activity may be neglected as being very nearly unity (pure iron in the liquid state being taken as the standard state). Since the solution is very dilute, the activities of manganese and of FeO in solution should be proportional to their concentrations, and thus the equilibrium expression becomes,

$$K'_{(7)} = \frac{1}{[Mn]\,[FeO]}$$

the quantities in brackets representing concentrations. This equilibrium is determined by the relative oxygen, or dissociation, pressures of the reactions

$$Fe + {}^1/_2O_2 \rightleftarrows FeO \qquad (9)$$

$$Mn + {}^1/_2O_2 \rightleftarrows MnO \qquad (10)$$

Using equation (8), LeChatelier obtained the values of 10^{-8} and 10^{-14} atmospheres for the respective oxygen pressures of FeO and MnO at 1600° C. Now for the substances of equation (7) present as separate, pure phases, equilibrium would not attain until the reaction was completed from left to right, because only then would the oxygen pressure of all phases be equal. With the substances dissolved in each other as in the actual slag–metal system, equilibrium will still leave certain concentrations of Mn and FeO present in the metal phase. LeChatelier apparently attempted to represent this condition by making the following quite impossible assumptions, (1) that the oxygen pressure of a saturated solution of FeO in iron (1.1% FeO assumed) would equal that of pure FeO multiplied by the weight concentrations, and (2) that such a solution would be in equilibrium with a pure MnO slag phase. This method gave a constant represented by the upper curve in Fig. 11.

McCance made a similar calculation using somewhat less approximate formulas based upon the Nernst heat theorem. Using his formulas and the maximum solubility value for FeO in iron as 1.125%, Oberhoffer and Schenck obtained the middle curve in Fig. 11. The agreement here between calculated and observed values is quite remarkable, considering the various doubtful, or incorrect, assumptions involved in the calculations. As an instance of these, a slag layer, or inclusions, of pure MnO can never be in equilibrium with a metal phase in which a part of the total oxygen is present as FeO, because it is a prerequisite of complete equilibrium that the total oxygen pressures of slag and metal must be identical.

The equilibrium constant for reaction (7), including the MnO concentration, becomes

$$K''_{(7)} = \frac{[MnO]}{[FeO][Mn]}$$

where the quantities in brackets refer to the molecular con-

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[11] Oberhoffer, P., & Schenck, H., Theoretische und experimentelle Untersuchungen über die Desoxydation des Eisens mit Mangan. *Stahl und Eisen*, Vol. 47 (1927), pages 1526–1536.

[12] LeChatelier, M. Henry, La Reduction de l'Oxyde de Fer. *Revue de Metallurgie*, Vol. 9 (1912), pages 513–522.

[13] McCance, A., Balanced Reactions in Steel Manufacture. *Transactions Faraday Society*, Vol. 21 (1925), page 188.

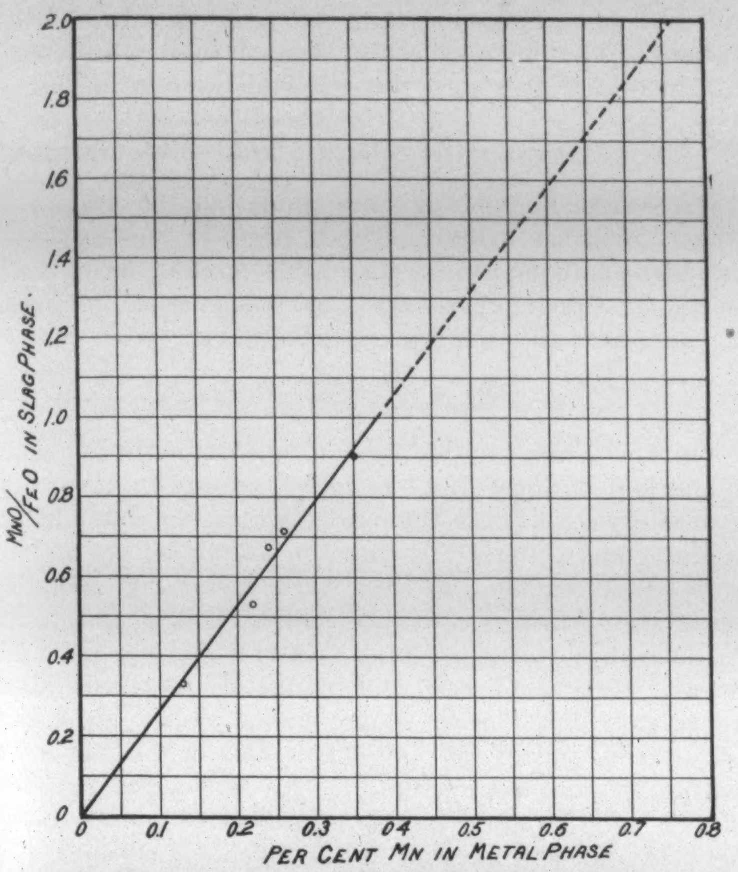

Fig. 12—Curve Showing Relation at Equilibrium between Residual Mn Contents in the Iron with the MnO/FeO Ratio in the Inclusion or Slag Layer in Contact with the Iron at around 1600° C. (*after Oberhoffer and Schenck*).

centrations in the metal phase. If we assume that the respective concentrations in slag and metal are directly proportional, and indicate the slag concentrations by formulas in parentheses, then

$$[\mathrm{MnO}] = \mathrm{C_1(MnO)}, \qquad [\mathrm{FeO}] = \mathrm{C_2(FeO)}$$

and

$$[\mathrm{Mn}] = \frac{1}{\mathrm{K''}_{(7)}} \cdot \frac{[\mathrm{MnO}]}{[\mathrm{FeO}]} = \frac{\mathrm{C_1}}{\mathrm{K''}_{(7)}\mathrm{C_2}} \cdot \frac{(\mathrm{MnO})}{(\mathrm{FeO})}$$

On this basis if the ratio $\frac{\mathrm{MnO}}{\mathrm{FeO}}$ for the slag layer is plotted against the manganese content of the metal, the points should be approximately on a straight line. In most of the melts of Oberhoffer and Schenck, the small amounts of slag phase formed were absorbed into the porous walls of the magnesite crucibles used. In a few melts, however, a few milligrams of slag were formed on the top of the ingots after cooling; and these tiny samples were analyzed for the relative amounts of iron and manganese by a colorimetric method. The results, plotted as above in Fig. 12, do lie approximately on a straight line. Fig. 13 represents these data plotted in terms of MnO contents in the slag which are in equilibrium with various manganese concentrations in the metal. Assuming the data to be accurate, this curve should represent the composition of the various FeO–MnO inclusions formed in deoxidation with manganese, with varying percentages of residual manganese in the metal. The accuracy of these data is very uncertain, however.

The data of Oberhoffer and Schenck do not seem to give definite values for equilibrium constants, the $\mathrm{K''}_{(7)}$ $[= [\mathrm{Mn}][\mathrm{FeO}]]$ values ranging from 1.8 – 1.1. By assuming a maximum solubility of 0.035% for MnO in iron under pure MnO slag, and using Fig. 13 to calculate the relative change in MnO concentration in the metal, we find calculated values of $\mathrm{K''}_{(7)} \left[= \frac{[\mathrm{MnO}]}{[\mathrm{Mn}][\mathrm{FeO}]}\right]$ varying from around 7 to 30. Using the slag compositions given by Fig. 13 and the equation

$$\mathrm{M} = \mathrm{N_1}x + \mathrm{N_2}y$$

discussed in a previous section, we find negative values for x, the maximum solubility of MnO in the liquid iron phase. The authors themselves, by another method of calculation, obtained negative values for the equilibrium constant. The accuracy of their results remains, therefore, somewhat uncertain. Nevertheless, their curve in Fig. 11 probably represents the most nearly accurate data for the equilibrium now available. The experimental difficulties involved in such measurements are very great. If the melts could be cooled more rapidly from the equilibrium temperature, and if the crucibles used could be made nearly impervious to slag absorption so that a definite layer of slag could be maintained over the metal, more consistent results might be obtained. Accurate manganese analyses are quite easily made, but in the determination of total oxygen, not only are the analyses very difficult, but there is danger of segregation because nearly all the oxygen in the solidified melts has been precipitated from solution in the form of oxide globules of various sizes.

The System FeO–MnO

Partly because of the difficulty of preparing and keeping the oxides in the pure state, and partly because of the lack of crucibles which are satisfactory for preparing synthetic melts of these oxides, the FeO–MnO system has received almost no systematic study. Platinum crucibles may be used, but are attacked and contaminated somewhat by the FeO. Most refractory crucibles are dissolved rapidly by the molten oxides, and the liquid tends to be soaked up by the porous crucible walls. To a greater or less extent, these same difficulties attend the preparation and study of all the oxide systems containing FeO or MnO, especially the former. Pure platinum, or Pt–20% Rh alloy, crucibles are probably best for the preparation of pure oxide mixtures, except for the expense involved in deterioration of the crucible material. Pure magnesia crucibles, made up as strong and dense as possible and then glazed on the inside surface with an electric arc, might overcome the corrosion by, and absorption of, the melts. Some work has been done leading to a technique for making such crucibles. Similar crucibles of zirconia or thoria offer interesting possibilities.

The oxygen pressures of all these slag mixtures are so low that to prevent oxidation to form $\mathrm{Fe_3O_4}$ and $\mathrm{Mn_3O_4}$, the melts must first be made under strongly reducing conditions and always remelted in vacuum or in a neutral atmosphere. Contact between the slag mixture and a liquid metallic iron phase is probably the best means for keeping all the iron in the slag in the form of FeO, which condition is probably approached in steel-making furnaces at the slag-metal interface. These conditions all point to the necessity for such nearly perfect refractory crucibles as would maintain a liquid slag and a liquid iron phase in contact with each other without either absorbing much of the slag or seriously contaminating the melts; and apparently, until such crucibles have

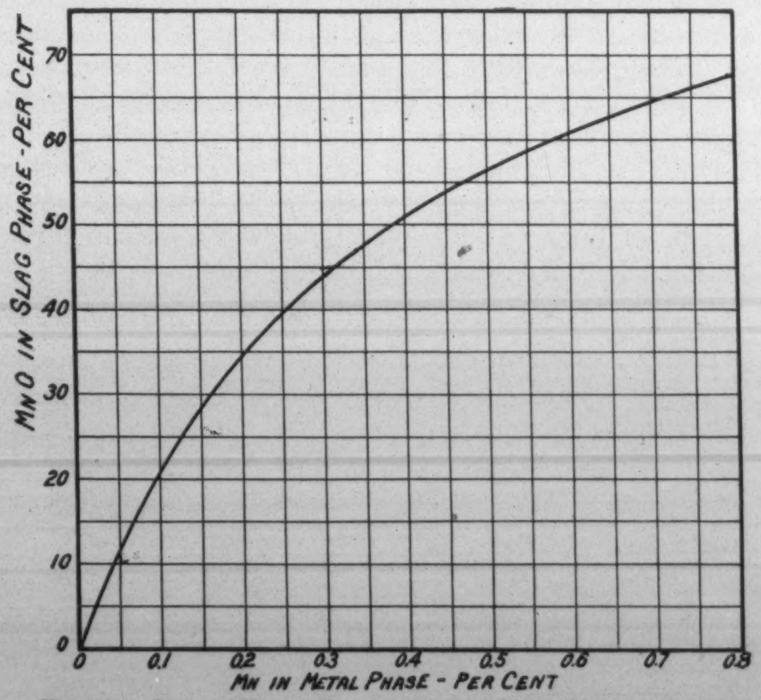

Fig. 13— Data of Fig. 4 Recalculated to Show Relation between Residual Manganese in Metal Phase with Various MnO Contents in Inclusions or Slag Layer.

been developed, we cannot expect to have first-rate data on the slag-metal equilibria and the slag systems which are so important in steel-making.

From their similarity in chemical and physical properties, MnO and FeO might be expected to form a simple solid solution system. Wyckoff[14] gives both as crystallizing in the cubic system, NaCl type, with unit cell dimensions of 4.29 A. U. for FeO and 4.40 A. U. for MnO, with calculated densities of 5.99 and 5.50, respectively. The melting point of MnO is given by Tiede[15] as about 1650°. Oberhoffer and von Keil[16] obtained the following melting temperatures on MnO–FeO mixtures in an iridium furnace under a pure nitrogen atmosphere:

Pure FeO	1390°
75% FeO + 25% MnO	1470°
50% FeO + 50% MnO	1513°
25% FeO + 75% MnO	only sintered at 1650°

Matveieff[17] reports the appearance of duplex structures in inclusions which were supposed to consist of only MnO and FeO. From such fragmentary data, Benedicks[18] has drawn a diagram for the system indicating two series of solid solutions, but this appears hardly warranted even as a preliminary sketch of equilibria involved. At least the melting points available indicate that the MnO–FeO particles formed during deoxidation in most ordinary rimmed steels should be liquid at the deoxidation temperatures (1550–1625° C.) and should coalesce easily to form larger particles which would rise rapidly in the liquid metal. Such inclusions are apparently[19] gray in color, somewhat darker in shade than pure FeO inclusions; they are more easily attacked by acids and less easily reduced by hydrogen as their MnO content increases. No sharp distinction from nearly pure FeO inclusions, as given by Campbell and Comstock,[20] is to be expected. Matveieff[17] states that the amount of MnO may be indicated roughly by reducing with hydrogen at red heat and cooling in the same hydrogen atmosphere, repolishing lightly and treating with an alcoholic solution of $FeCl_3$; inclusions largely composed of MnO are not reduced, mixtures of "MnO with some FeO" are colored deeply by the $FeCl_3$, whereas pure FeO is colored feebly.

FeO–MnO inclusions will be found only in steels which contain not more than a trace of silicon, and in which no silicon has been used in deoxidation at the end of the heat. If some residual silicon is present along with manganese, the inclusions will contain more or less of silicates such as $2FeO \cdot SiO_2$, $MnO \cdot SiO_2$ and $2MnO \cdot SiO_2$. Most "rimmed" steels, however, are made with ferromanganese as the only deoxidizer (except for the small amounts of aluminum often added in the molds) so that in these steels $FeO \cdot MnO$ inclusions will probably comprise the greater part of the oxide inclusions. Both oxides are quite soluble in dilute acids and are, therefore, difficult to separate from the iron matrix by most solution methods. The Dickenson method,[21] for example, does not recover appreciable amounts of either $MnO \cdot FeO$ or FeO inclusions. MnO, especially, seems to be soluble even in solutions containing no hydrogen ions beyond those formed by the hydrolysis of iron salts in aqueous solution. For this reason, a bromine—KBr—water solution will give poor and uncertain recoveries of MnO–FeO inclusions. The iodine-absolute alcohol solution method of Willems[22] may give good recoveries of these inclusions.

IV. Deoxidation with Silicon: FeO–SiO_2 Inclusions

The system Fe–Si–O is quite similar to the system Fe–Mn–O. SiO_2 has a lower oxygen pressure and apparently a smaller solubility in iron than MnO, so that silicon is what we call a "stronger deoxidizer" than manganese. McCance[13] has calculated the equilibria in the reaction

$$FeO + Si \rightleftarrows Fe + SiO_2 \qquad (11)$$

in a manner similar to that used in calculating the manganese equilibrium outlined in a previous section. In view of the uncertainty involved in these calculations, the data obtained by Herty and Fitterer[23] by direct measurement are probably more nearly reliable. In their work, increasing amounts of ferrosilicon were added to small ladles of metal (10–15 lbs.) from a bath of steel containing around 0.05% carbon, 0.04% Mn and 0.30–0.35% FeO, and the metal was poured almost immediately into 3-inch square metal molds. Inclusions, total silicon, and oxygen present as FeO in the ingots were determined; and the amounts of free silicon and oxygen in solution (in the liquid metal) were derived by subtracting the FeO and SiO_2 present in the silicate inclusions. The equilibrium concentrations calculated in this manner are necessarily approximate, because, (1) the Dickenson method used to determine inclusions gives poor recoveries of FeO; (2) the metal contained some manganese and carbon which might have an effect on the Fe–Si–O equilibrium; and (3) no temperature measurements were made, nor was any attempt made to hold the metal for even a short time at some definite temperature, to ensure the attainment of equilibrium. The results, plotted in Fig. 14, show points so scattered that the curve can be only a rough approximation.

The results of this work indicate that the mechanism of deoxidation with silicon is about as follows: When ferrosilicon is added to a bath high in FeO, it goes into solution very rapidly; the silicon reacts rapidly with FeO to form SiO_2 which is but slightly soluble and begins to separate from solution. At the same time this precipitated SiO_2 tends to absorb FeO from the metal, in order to satisfy the distribution equilibrium for both FeO and SiO_2 between metal and slag phases. This fluxing process is apparently much slower than the reaction in the metal phase, especially if the slag particles are high in silica and very viscous, so that the inclusions formed first seem to be nearly pure silica, gradually increasing in FeO content as they remain longer in contact with the iron phase.

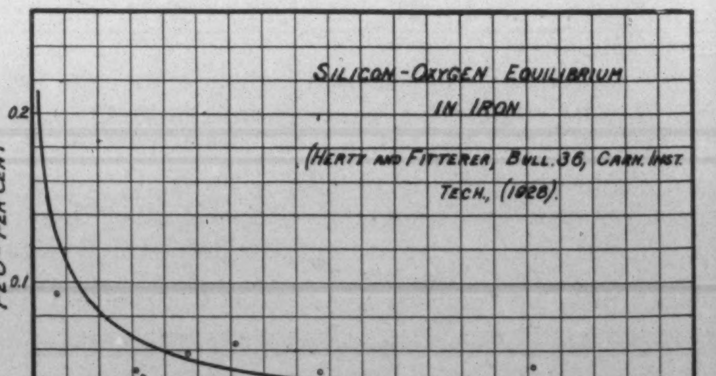

Fig. 14—Experimental Data on the Residual Silicon and Oxygen Contents at Equilibrium in the Reaction FeO + Si. Fe + SiO_2 in Liquid Iron (*after Herty and Fitterer*).

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[14] *International Critical Tables*, Vol. I, page 342. McGraw-Hill Book Company, 1926.

[15] Tiede, E., & Birnbräuer, E., Spezielle Arbeitsmethoden zur Erzeugung hoher Temperaturen im Vakuum und das Verhalten einiger Metalle, Oxyde und Karbide bei denselben. *Zeitschrift für anorganische Chemie*, Vol. 87 (1914), page 162.

[16] Oberhoffer, P., & von Keil, O., Ueber ein neues Verfahren zur Bestimmung des Sauerstoffs im Eisen. *Stahl und Eisen*, Vol. 41 (1921), pages 1449–1453.

[17] Matveieff, M. M., Méthodes métallographiques pour déterminer la Nature des Inclusions non metalliques contenues dan l'acier, le fer et la fonte. *Revue de Métallurgie*, Vol. 17 (1920), pages 736–752.

[18] Benedicks, C., & Löfquist, H., Present Knowledge Regarding Slag Inclusions in Iron and Steel. *International Congress for Testing Materials*, Amsterdam, Sept. 1927.

[19] Wohrman, C. R., Inclusions in Iron. *Transactions American Society for Steel Treating*, Vol. 14, July 1928, pages 81–126.

[20] Campbell & Comstock, Determinations of Inclusions in Steel. *Proceedings American Society for Testing Materials*, Vol. 23 (1923), page 522.

[21] Herty, C. H., Jr., & Fitterer, G. R., A Study of the Dickenson Method for the Determination of Non-metallic Inclusions in Steel. *Cooperative Bulletin* 37, *Mining & Metallurgical Advisory Boards*, Pittsburgh, Pa. (1928).

[22] Willems, F., Beitrag zur Bestimmung von Oxyden im Stahl. *Archiv. für das Eisenhüttenwesen*, Vol. 1, April 1928, pages 655–658.

[23] Herty, C. H., Jr., & Fitterer, G. R., Deoxidation with Silicon and the Formation of Ferrous-silicate Inclusions in Steel. *Cooperative Bulletin* 36, *Mining & Metallurgical Advisory Boards*, Pittsburgh, Pa. (1928).

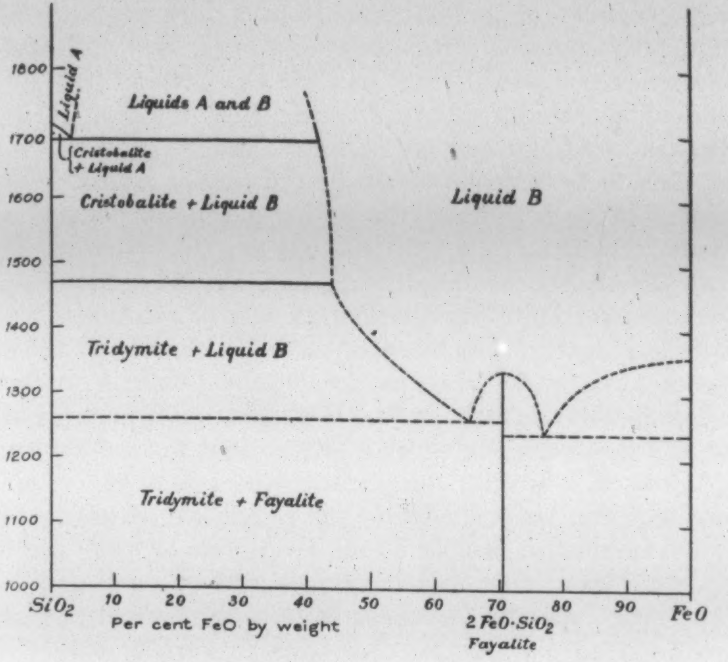

Fig. 15—Preliminary Equilibrium Diagram for System FeO–SiO$_2$

The system FeO–SiO$_2$ has been studied by Whiteley and Hallimond,[24] von Keil and Dammann,[25] Greig,[26] and Herty and Fitterer[23]; the diagram given in Fig. 15, taken chiefly from the results in the last two papers may be considered a good first approximation. One stable compound, fayalite or 2FeO·SiO$_2$, is formed, and a region of immiscibility exists up to around 40% FeO, with three eutectics, at around 3.5, 65 and 77% FeO. The melting-temperature rises rapidly as the SiO$_2$ content rises above 50%, from around 1425° C. at 55% SiO$_2$ to the melting point of the liquid A eutectic at 1690° C., when the SiO$_2$ content is above 60%.

The inclusions formed with varying amounts of residual silicon in the metal were studied by Fitterer[23] and accord with what would be expected from the equilibrium diagram. If sufficient silicon is added so that around 0.05–0.06% or more of dissolved silicon remains in the steel after the deoxidation reaction is completed, the inclusions are spherical particles of extremely viscous silica glass, containing 60–90% or more of SiO$_2$. These glassy particles are transparent, and in polished sections give peculiar reflections from the bottom of the sphere. With less residual silicon in the metal the FeO content in the inclusions rises, the inclusions become somewhat larger, having a duplex structure of light gray FeO crystallized in a darker gray background which under a high magnification may often be resolved into a fine-grained eutectic of fayalite and FeO. In other cases excess fayalite or a high-silica phase (darker) were found together with one of the eutectics. These intermediate types usually occurred with a residual silicon content of 0.005–0.04%; they were usually larger and more nearly crystalline, indicating that they had been present in the steel as liquid globules which could coalesce easily and which probably froze only after solidification of the metal. With no silicon addition, only the very small, light gray, FeO inclusions were present.

The high-silica glassy inclusions are easy to separate from the steel by most extraction methods, but inclusions consisting largely of fayalite and FeO are quite soluble in acids and are more difficult to recover, being almost completely dissolved in the Dickenson method. The iodine method of Willems and probably Amman's bromine method should both recover most of the FeO or fayalite present.

Although, according to Fig. 15, none of this series of FeO–SiO$_2$ mixtures should be liquid at ordinary soaking-pit temperatures (1100°–1200° C.) the intermediate silicate types (especially the larger globules) are usually found much elongated into stringers after forging. The glassy high-silica inclusions are almost unaffected by working the metal, the larger ones being slightly elongated into ellipsoids. The tiny spherical FeO inclusions also remain practically unaffected by forging.

Distribution of FeO between Iron and Acid Slags

In the discussion on the Fe–O system, we concluded that if, to a system composed of a pure FeO slag in contact with iron saturated with FeO, such oxides as MgO or CaO were added, the only effect would be a simple dilution of the FeO and that as a good approximation, the FeO concentration in the metal phase could be assumed to be lowered in direct proportion to its decreasing concentration in the slag. This is based on the assumptions that (1) the oxygen pressures of MgO and CaO are negligible in comparison to that of FeO, these oxides being not appreciably reduced by iron, and (2) they form essentially "ideal" solutions with liquid FeO. With FeO-MnO mixtures also, the second assumption may be approximately accurate, the two oxides being very similar in properties and forming no compounds. The only difference in the effects of MnO and CaO then lies in the fact that the former is appreciably soluble in iron and is appreciably reduced by iron, so that some manganese is introduced into the metal phase.

When SiO$_2$ is introduced into such a Fe–O system, the equilibrium conditions are further modified owing to the formation of a stable compound, 2FeO·SiO$_2$, with the FeO in the slag phase. From the rough measurements of equilibrium given above, we know that SiO$_2$ is appreciably reduced by iron, though to a much smaller extent than MnO. SiO$_2$ may also have a measurable solubility in liquid iron, but this must be very small, certainly less than 0.02%. Fayalite may then reasonably be assumed to be not measurably soluble as 2FeO·SiO$_2$ molecules in liquid iron.

The distribution law of a solute between two liquids is based on the conception of the distributed substance having the same molecular form in both solvents. Therefore, since fayalite is considered insoluble in the iron phase, any molecules of FeO which are combined to form fayalite in the slag take no part in the distribution equilibrium of FeO between slag and metal phases. If a slag phase of pure fayalite is melted on the surface of liquid iron, the only FeO in the slag which is available for solution in the metal is that present as "free" FeO molecules formed by dissociation of fayalite,

$$2\text{FeO}\cdot\text{SiO}_2 \rightleftarrows 2\text{FeO} + \text{SiO}_2 \qquad (12)$$

Fayalite is almost certainly a stable compound in the solidified melts, but there is practically nothing to determine the extent of dissociation in the liquid state. Making use of the assumptions outlined above, Herty and Gaines[27] have tried to determine the degree of dissociation by melting electrolytic iron under a ferrous silicate slag in a thick-walled silica crucible in an induction furnace, the melts being exposed to the air. The following results are given as more or less preliminary values.

$K_{(12)} = \dfrac{(\text{FeO})^2\,(\text{SiO}_2)}{(2\text{FeO}\cdot\text{SiO}_2)} = \dfrac{\alpha^3}{(1-\alpha)}$ where α represents the ratio of dissociated molecules to the total number of fayalite molecules present.

Temp. ° C.	$K_{(10)}$	α
1550	0.063	0.345
1600	0.480	0.584
1650	2.06	0.774

The experimental conditions encountered here are extremely bad, and the results can be regarded only as roughly quantitative. Such data are, however, of really practical importance, since they not only help to explain the equilibria in deoxidation with silicon but are intimately connected with the fundamental differences between the acid open-hearth and basic open-hearth processes.

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[24] Whiteley, J. H., & Hallimond, A. F., The Acid Hearth and Slag, *Journal Iron & Steel Institute*, Vol. 99 (1919), pages 199–255.

[25] von Keil, O., & Dammann, A., Beitrag zur Kenntnis des Zustandsdiagramms Eisenoxydul und Kieselsäurel. *Stahl und Eisen*, Vol. 45 (1925), page 890.

[26] Greig, J. W., On Liquid Immiscibility in the System FeO-SiO$_2$. *American Journal of Science*, Vol. 13 (1927), pages 1–14, 133–154.

[27] Herty, C. H., Jr., Physical Chemistry of Steel-making, *9th Progress Report*, Feb.-May 1929.

V. Deoxidation with Aluminum

The deoxidizing reaction of aluminum in iron

$$3FeO + 2Al \rightleftarrows Al_2O_3 + 3Fe \qquad (13)$$

appears to go nearly to completion from left to right, and the equilibrium concentrations of FeO and Al present together in solution are so small as to be difficult to measure accurately. They are probably smaller than those for silicon deoxidation (Fig. 14) but no measurements have been made which can be regarded as better than roughly qualitative in character. To obtain accurate data it will be necessary to take samples deoxidized to various degrees with aluminum, determine their content of inclusions accurately, and analyze these inclusions for FeO and Al_2O_3, then determine the total FeO content and the amount of aluminum present as metal in the iron. The accurate determination of small amounts of metallic aluminum in the presence of such a large excess of iron is an especially difficult analytical procedure. It will be necessary to develop more exact methods of analysis for inclusions, total oxygen, etc., before this equilibrium can be measured with even the approximate degree of accuracy indicated above for the Si–O–Fe system.

The system Al_2O_3–FeO has not been studied. One compound of the spinel type, which is called hercynite ($FeO \cdot Al_2O_3$) is rarely found occurring as a natural mineral.

The inclusions formed by pure aluminum are very small and hard Al_2O_3 particles, which often show rough crystal outline. They may often contain some FeO in solution, but the melting point of pure Al_2O_3 is 2050° C. and in most cases the inclusions formed probably have melting points far above the temperatures of the iron solution from which they are precipitated. Aluminum is nearly always used as the final deoxidizing addition to combine with most of the last portion of FeO left in the metal. If to a melt high in FeO, a small amount of aluminum is added, there is a certain range in which the inclusions formed are black globules, small but larger than the ordinary Al_2O_3 particles, and which show evidence of having been liquid at some time after their formation. In all commercial steels, however, the alumina inclusions present have apparently never been present in the iron as globules sufficiently fluid to coalesce and form larger particles, as is usually the case with most other types of oxide and silicate inclusions, even the glassy, high-silica type, formed in deoxidation with silicon, which probably is a very viscous fluid after formation.

Since alumina inclusions are nearly always formed as solid particles, they do not coalesce to form larger particles in the liquid metal. They do, however, seem to have a tendency to group together in bunches or small "clouds" of particles. In steels containing relatively large numbers of alumina inclusions, these groups during forging or rolling are formed into irregular rows of particles strung along close together in the direction of working. The individual particles are rarely larger than a few microns in diameter and a certain proportion of them are probably submicroscopic. Like FeO, they have a tendency to cause abnormal structures in carburized steels. Even the largest of them are not much above the colloid range of sizes and have a slow rising-rate in liquid steel. They are about the most difficult inclusions to polish well in cut sections, and ordinary methods of polishing yield nothing but tiny black pits or streaks in which the individual particles cannot be distinguished. They are very resistant to attack of nearly all etching reagents; in deep etching with acids, the iron immediately adjacent to the inclusions is attacked more rapidly, and some of the particles may fall away from the metal when the iron around them is corroded away.

Aluminum in the form of shot or wire is often used to "kill" small samples of metal taken from a furnace bath which commonly contains certain amounts of C, FeO and MnO in solution which would react to form CO gas and thus evolve bubbles so rapidly during freezing that the sample ingots obtained would be very porous and would also give low values for carbon content due to the loss of carbon as carbon monoxide. In such samples the added aluminum should react nearly quantitatively with all oxygen dissolved as MnO, FeO, CO or other oxides, leaving Mn, Fe and carbon in solution, and precipitating the oxygen out of solution as Al_2O_3 particles. Herty[28] has recently used this reaction as the basis of a method for determining the dissolved oxygen content of liquid steel in a furnace bath. If a spoonful of metal is taken out in a ladle well coated with slag so that the metal remains at nearly the furnace temperature until a length of aluminum wire can be pushed into the metal (an excess of aluminum is necessary, usually about 4–5 grams or more per 1000 gms. steel) and then poured and frozen quickly in a small metal mold, the Al_2O_3 content of this sample will be closely equivalent to the oxygen dissolved as various oxides, but chiefly FeO, in the steel bath. The Al_2O_3 particles are extracted by dissolving away the iron in 20% HCl.

VI. Deoxidation with Carbon

The system C–Fe–O consists of only two phases, liquid metal and gas, if more than a trace of carbon is left in the metal. The deoxidation reaction

$$FeO + C \rightleftarrows CO + Fe \qquad (14)$$

is prevented from going to completion by the carbon monoxide in solution in the metal. Since this CO concentration varies with the partial pressure of carbon monoxide in the gas phase, under a very good vacuum it should be possible to deoxidize iron almost completely with only a few hundredths of one percent of carbon left in solution in the metal. In ordinary practice, however, to attain any speed either of deoxidation or carbon elimination, it is necessary that bubbles of CO gas be formed throughout the body of the liquid metal, and in furnace or ladle reactions the CO concentration must be the saturation value under approximately one atmosphere pressure CO. The few available data[29] indicate that the solubility of gases in metals increases with temperature, and if this is true for CO in iron, higher temperature should tend to oppose the reaction. The reaction is, however, definitely endothermic, wherefore the reaction toward the right would be favored by higher temperature, which seems to be true from the rough data available.

The equilibrium constant,

$$K_{(14)} = \frac{(CO)}{(FeO)(C)}$$

may be expressed as

$$K'_{(14)} = \frac{1}{(FeO)(C)}$$

with the assumption of a constant effective CO pressure. Herty and Gaines[3] calculated values for this constant over a range of temperatures from open-hearth data, with the results given in Fig. 16, expressed in terms of equilibrium values for carbon and oxygen. The main assumption involved is that equilibrium was actually attained in the open-hearth heats studied; even though this was not entirely valid, the data, since they are derived directly from commercial open-hearth conditions, should be applicable to open-hearth problems under the conditions of ordinary American practice.

This system might be studied by making melts of iron, carbon and FeO in a vacuum furnace, obtaining equilibrium in several series of melts, in each of which a definite CO pressure and temperature was maintained, but with a varying

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[28] Herty, C. H., Jr., Gaines, J. M., Freeman, H., & Lightner, M. W., A New Method for Determining Iron Oxide in Liquid Steel. *Technical Publication* No. 311, *American Institute of Mining & Metallurgical Engineers*, Feb. 1930.

[29] *International Critical Tables*, Vol. 3, page 270, 1928.

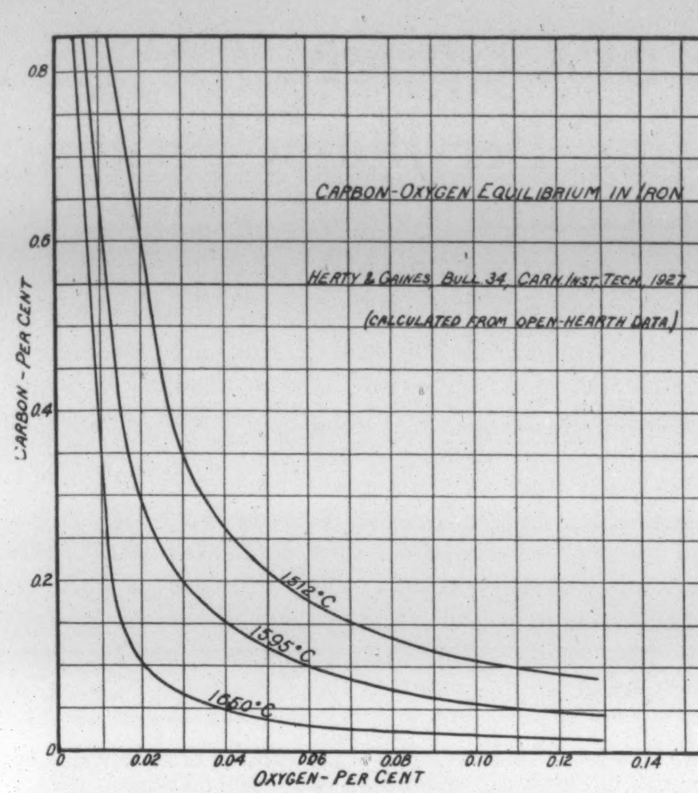

Fig. 16—Calculated Equilibria for the Reaction FeO + C–Fe + CO in Liquid Iron Solution, Showing Residual Oxygen and Carbon Contents

carbon content. The chief problem here is to "freeze" the equilibrium before cooling the melt or to determine the amount of CO absorbed by following the pressure changes and measuring the total weight of CO introduced into the system. If feasible, it would be simpler to freeze the equilibrium, perhaps by adding excess aluminum to the melt, then quickly to evacuate the furnace and cool the melt rapidly; the Al_2O_3 content of the ingot should then represent the product of reaction with the total CO + FeO present at equilibrium. In such a series of melts with constant temperature and CO pressure but with increasing carbon content, the total oxygen present should tend to approach a limiting value which would represent the solubility of CO at that temperature and pressure. An attempt should be made to approach the equilibrium from both sides. If, for example, the initial melt was free of oxygen, it would probably be quite difficult to saturate the melt with CO without actually bubbling the gas through the molten metal. On the other hand, if the initial charge was a mixture of an iron-oxygen alloy and carbon, CO evolution might cease at an internal pressure considerably above that of the CO atmosphere above the melt. The crucibles used should be of material extremely low in oxygen pressure, such as very pure MgO absolutely free of all oxides such as Al_2O_3, SiO_2 or TiO_2 which might be reduced by the iron-carbon solution and disturb the equilibrium to be measured.

Feild[30] has discussed some of the varying values obtained for $1/K'_{(14)}$ by various direct and indirect methods. Herty has computed values, based on open-hearth data, which are all in the neighborhood of 0.01–0.03 for temperatures around 1550–1600° C. Kinzel and Egan[31] attempted to measure the equilibrium directly and obtained a series of values all of which were very close to 0.0005 for 1550° C. Calculations using the equilibrium and specific heat data of Eastman[1] give a value around 0.0016, which is closer to the value of Kinzel and Egan than to those of Herty. The many assumptions involved in such calculations make this corroboration of very little value, however. The probable sources of errors in Kinzel and Egan's work all tended to give low values, and they did not furnish adequate proof that equilibrium was either attained in the melts or "frozen" during cooling of the furnace. Until further direct measurements are made, the results given in Fig. 16 seem to be the most nearly reliable, at least for purposes of calculation in open-hearth reactions.

In reaction (14), a certain amount of CO_2 should theoretically be formed (rather than 100% CO) as the product of the reaction. Calculations from equilibrium data indicate that something like 96% CO and 4% CO_2 should be in equilibrium with a metal containing 0.01% oxygen. This indicates that the gases evolved from killed steels should contain only very small amounts of CO_2.

The solubility of CO probably decreases slowly during cooling to the melting point and then rapidly during solidification to a relatively negligible amount in the solid metal. Additional CO may be formed during freezing, because of the tendency for nearly pure iron to separate first, leaving both carbon and FeO concentrated in the remaining liquid portions. This should destroy the equilibrium between carbon and FeO in this liquid portion, causing the formation of CO in excess of the amount present as such in the liquid melt. These changes make CO the principal constituent of the gases evolved during the solidification of "rimmed" and "semi-killed" ingots.

The C–FeO, Mn–FeO and Si–FeO equilibrium curves considered approximately valid for about 1600° C. are given for comparison in Fig. 17. From these curves, it is evident that a "rimmed" steel containing 0.04% O_2 in the liquid melt, could have as much as about 0.15% carbon and 0.28% Mn, but no larger percentages, and must contain only traces of dissolved silicon. Since the manganese curve lies wholly above the carbon curve, it is apparently not possible to "kill" a steel with ferromanganese alone. Steels containing more than about 0.1% silicon will usually be in the class of killed steels, those with about 0.03–0.06% Si should be semi-killed and those with 0.02% or less should be "rimming" or "wild" steels.

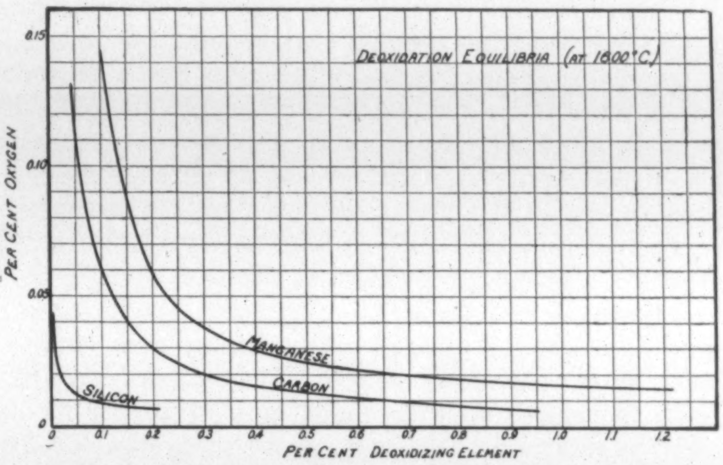

Fig. 17—Approximate Equilibrium Curves for Deoxidation with Carbon, Manganese and Silicon at 1600° C. in Liquid Iron; Showing Residual Amounts of Deoxidizers with Corresponding Oxygen Contents in Solution

(To be continued in October)

New Steel Publication

The first issue of "Steel"—a quarterly issued by the Subsidiary Manufacturing Companies of the U. S. Steel Corporations appeared in January, 1930. This issue contained a number of current advertisements scheduled to appear in numerous periodicals. In the foreword it is stated: "This selection shows a few representative advertisements, which it is felt will be particularly interesting and informative to all sales people and certain consumers, and therefore of value not only to the specific companies, but to the Corporation as a whole. It is believed that certain customers also will appreciate the information in this convenient form."

The second issue of this very interesting new publication contains a number of interesting articles in addition to the advertisements and also contains a list of the products of the U. S. Steel Subsidiary Companies. Articles which will be of special interest to the readers of METALS & ALLOYS are: "Some Comments on Steel Specifications," by Dr. John Johnston, which is reprint of some paper presented by the American Iron & Steel Institute Meeting in New York, and "1930 Corrosion Review" by Dr. F. N. Speller.

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[30] Feild, A. L., *Metals & Alloys*, Vol. 1 (1929), pages 279–281.

[31] Kinzel & Egan, *Technical Publication* No. 230, *American Institute Mining & Metallurgical Engineers*, Aug. 1929.

M. H. T.

The Deoxidation of Copper

With the Metallic Deoxidizers, Zinc, Beryllium, Barium, Strontium and Lithium

By Earle E. Schumacher,* W. C. Ellis* and John F. Eckel*

Introduction

This paper deals with the use of the metallic deoxidizers, zinc, beryllium, barium, strontium and lithium, in producing deoxidized copper and describes the properties of the resulting alloys. It is a continuation of an investigation[1] previously reported by the authors in which calcium was used for the same purpose.

Of the metals studied, it is well known that zinc and beryllium are effective deoxidizers of copper. The investigation of these two elements was undertaken, therefore, primarily to confirm the results of previous investigations and to present further data on the effect of these elements on the conductivity and mechanical properties of the resulting material.

The fact that zinc in small quantities will deoxidize copper can be predicted from the fact that commercial brass alloys are free from copper oxide. That zinc has a reasonably small effect on the conductivity of copper to make it of interest as a possible deoxidizer is evident from the published data on conductivity. One percent of zinc by weight increases the resistivity of copper, as reported in the data of a number of investigators,[2] approximately 0.28 microhm centimeter. This corresponds to a decrease of 14% in the conductivity.

Beryllium has been shown by Masing and Haase[3] to be effective in deoxidizing copper. The data in regard to the effect of beryllium on the conductivity of copper included in their report indicate, however, that this element has a comparatively large effect in decreasing the conductivity of copper.

In the case of the barium and strontium, little or no information has been published in regard to their use as deoxidizers. However, the high affinity of these elements for oxygen, together with the similarity of their chemical behavior to that of calcium, indicate their possibilities for this use.

It has been suggested that lithium has certain properties which make it of interest for the deoxidiation of copper. It is the only metallic deoxidizer, which has been considered in this report, with an oxide that is liquid at the temperature of molten copper. This may be advantageous in promoting the separation of the oxide slag from the liquid bath. The use of lithium in the deoxidation of copper has been described by Masing and Haase.[3] The element was found by them to be not entirely satisfactory for this purpose. The difficulties which were encountered are discussed in detail in the section of this paper devoted to the use of lithium.

Preparation and Working Properties of the Alloys

The method of preparing the alloys deoxidized with beryllium and zinc was similar to that used in the previous study of the deoxidation of copper with calcium.[1] In brief, it consisted of melting a three pound charge of cathode sheet copper under charcoal in an alundum lined graphite crucible heated in an electric resistance furnace. The deoxidizers were added after the copper had been removed from the furnace. After the addition had been made the melt was well stirred and then poured. In the case of the copper deoxidized with barium, strontium and lithium, melts of 200 grams were prepared in fused silica crucibles.

Whenever possible, the deoxidizer was added as an addition alloy with copper. In the case of zinc, a brass containing 34% zinc was used. The beryllium was added in a copper alloy containing 10.11% beryllium, which had been prepared previously by melting copper and beryllium in a fused silica crucible under an atmosphere of hydrogen. The barium and strontium were added as received from the suppliers, in the form of wire encased in a copper sheath. Lithium was added in a 10% copper alloy and also as pure metal wrapped in a copper foil.

The composition of the alloys as prepared and by chemical analysis are given in Table 1.

Table 1

Copper Alloys Prepared in the Study of the Effect of Some Metallic Deoxidizers on Copper

Melt No.	Deoxidizer	Weight % Added	Weight % by Analysis
1	None	0.0	...
2	Zinc	0.10	0.097
3	Zinc	0.20	0.183
4	Zinc	0.40	0.377
5	Beryllium	0.01	0.01
6	Beryllium	0.06	0.06
7	Beryllium	0.10	0.09
8	Barium	0.10	0.06
9	Barium	0.17	0.08
10	Barium	0.50	0.04
11	Barium	3.0	Trace
12	Strontium	0.10	0.03
13	Strontium	0.50	0.04
14	Lithium	0.08	0.04
15	Lithium	0.13	0.03

The tests and results given in this paper were made on wire of 0.104 inch diameter. The 0.750 inch cast bars were swaged to 0.250 inch rod, annealed and then drawn to the final size.

Properties of Copper Deoxidized with Zinc

The effect of zinc on the mechanical properties of the hard drawn copper wire is shown in Fig. 1. The ultimate strength remains quite constant while the proportional limit decreases slightly with the increase in zinc content. The elongation in 2 inches increases from 4.5% for tough pitch copper to 5.5% for the alloy containing 0.097% zinc and continues from this point to 0.377% zinc at an almost constant value. In general, zinc up to 0.4% has but a small effect on the mechanical properties of hard drawn copper wire.

The effectiveness of zinc as a deoxidizer in copper is shown in Fig. 2. The alloys containing zinc were not embrittled by annealing in hydrogen at 800° C. for one hour. This is evident from the close agreement of the values for ultimate strength and elongation of the corresponding alloys after air and hydrogen anneals.

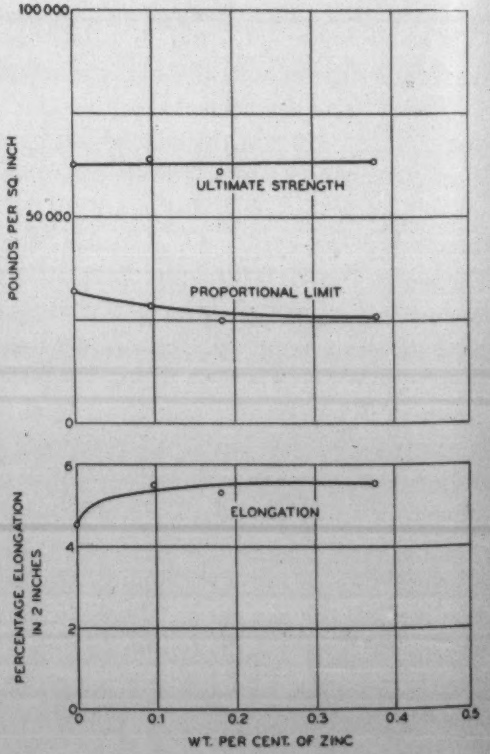

Fig. 1—Effect of Zinc on the Mechanical Properties of Hard Drawn Copper Wire

The excess of zinc resulting from the deoxidation of copper with this metal has a comparatively small effect on the conductivity of the copper. This is shown by the results for annealed and hard drawn specimens plotted in Fig. 3. Up to 0.3% each 0.05% of zinc remaining in the metal reduces the conductivity approximately 0.8%. By extrapolating these curves to 1.0% zinc, a value of about 84.0% is obtained for the conductivity. This is equivalent to an increase of 0.32 microhm centimeters, and agrees well with results of earlier investigators given in the first part of the paper.

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* Members of the Technical Staff, Bell Telephone Laboratories.

In one experiment, a laboratory melt of 6 pounds of cathode sheet copper was prepared to which was added sufficient copper oxide to bring the oxygen content to 0.04%. This melt was deoxidized with zinc. Wire drawn from the castings had a conductivity comparable to the results obtained with cathode sheet copper to which zinc had been added. The mechanical properties after a hydrogen anneal showed the material to be deoxidized.

Properties of Copper Deoxidized with Beryllium

The effect of beryllium on the mechanical properties of hard drawn copper wire is shown in Fig. 4. The ultimate strength increases slightly with the increase of beryllium content, while the % elongation decreases correspondingly.

The effectiveness of beryllium as a deoxidizer of copper is shown in Fig. 5. As in the case of zinc, the alloys containing beryllium were not embrittled by the hydrogen anneal. This is shown by the close agreement of tensile strength and elongation of the material annealed in hydrogen with the tensile strength and elongation of the same material annealed in air.

The conductivities of copper-beryllium alloys containing up to 0.1% beryllium in the hard drawn and annealed condition are plotted in Fig. 6. Reference to this figure shows that each 0.05% of residual beryllium retained in the metal reduces the conductivity approximately 10%. These results are in general agreement with those obtained by Masing and Haase.[3] This is evident from a comparison with a curve plotted in the same figure from data given by them. The results indicate that beryllium produces a comparatively rapid decrease in conductivity, and from this viewpoint, is less satisfactory as a deoxidizer of copper than either zinc or calcium.

The Properties of Copper Deoxidized with Barium and with Strontium

Four copper melts containing barium and two containing strontium were prepared. These melts together with the mechanical and electrical properties in the hard drawn and annealed condition are listed in Table 2. This table

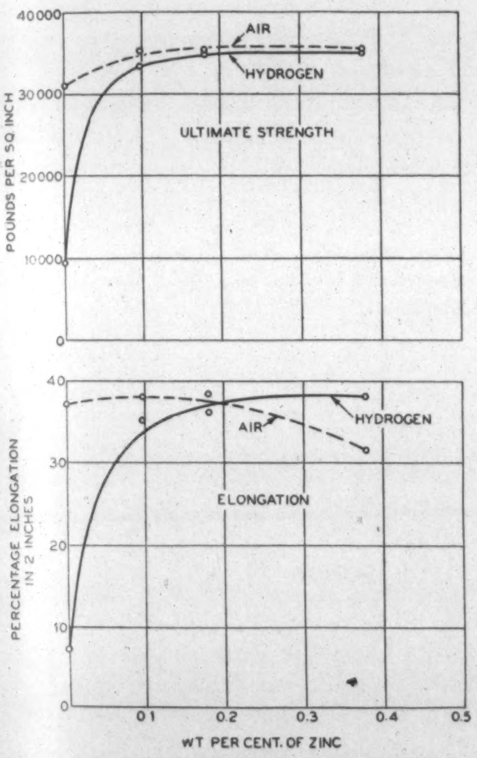

Fig. 2—Effect of Annealing in Hydrogen for 1 Hour at 800° C. on the Mechanical Properties of Copper-Zinc Alloys

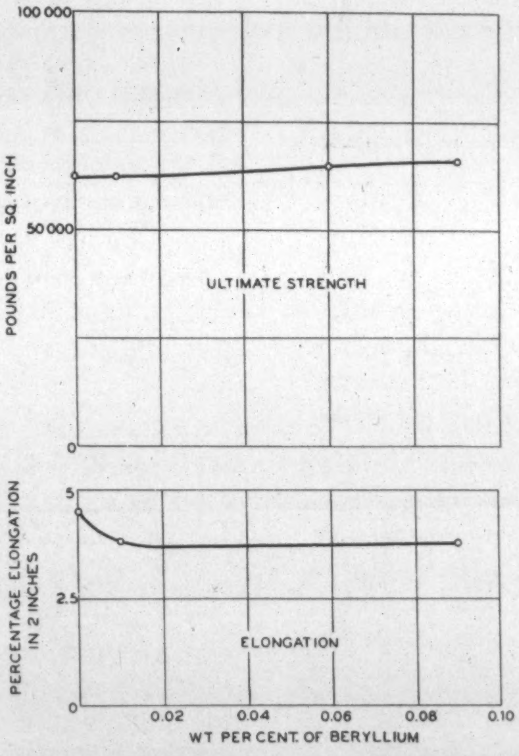

Fig. 4—Effect of Beryllium on the Mechanical Properties of Hard Drawn Copper Wire

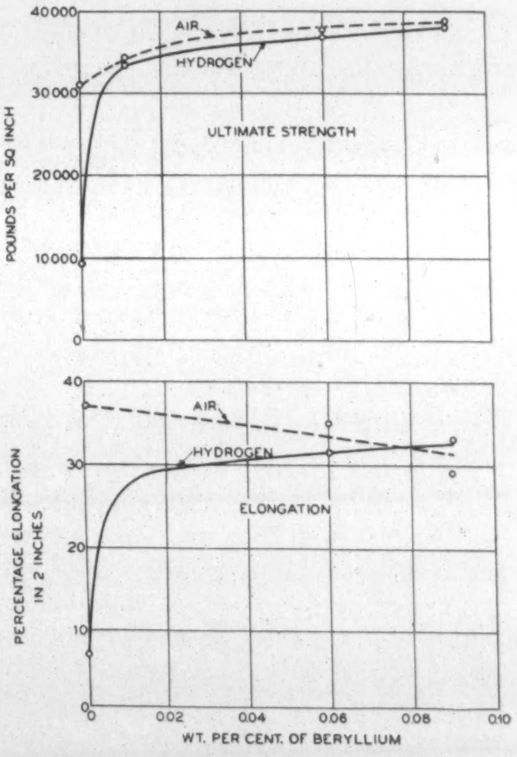

Fig. 5—Effect of Annealing in Hydrogen for 1 Hour at 800° C. on the Mechanical Properties of Copper-Beryllium Alloys

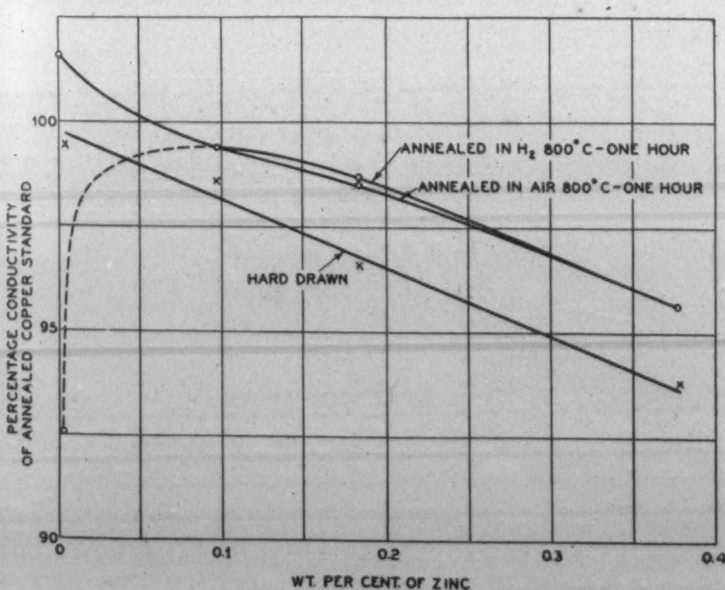

Fig. 3—Effect of Zinc on the Conductivity of Copper Wire at 20° C.

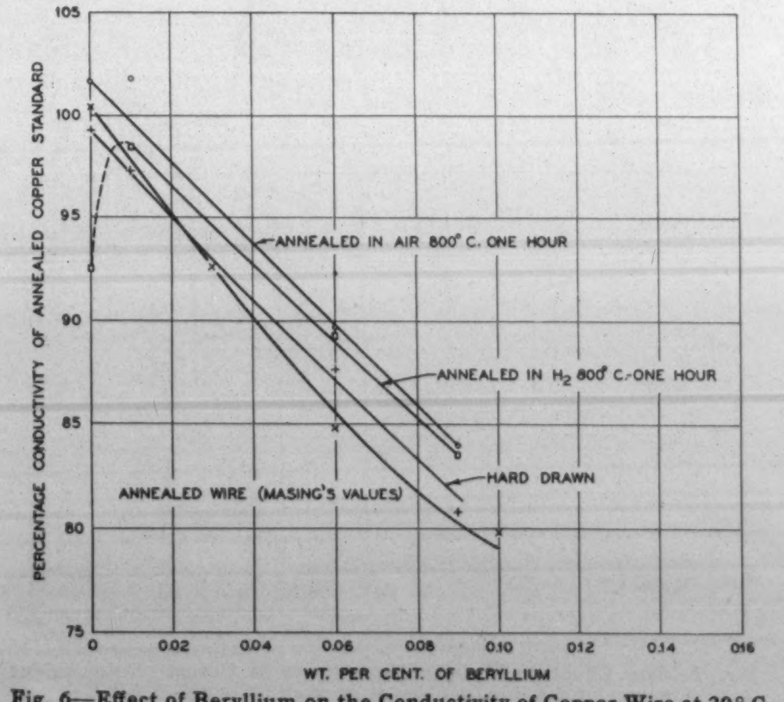

Fig. 6—Effect of Beryllium on the Conductivity of Copper Wire at 20° C.

Table 2
The Effect of Small Percentages of Added Barium and Strontium on the Properties of Copper

				Hard Drawn			Annealed 1 Hr. 800° C. in Air		
Melt No.	Added Element	% Added	% Analysis	Ultimate Strength Lbs./In.²	% Elongation in 2 In.	Electrical Conductivity % Annealed Copper Standard	Ultimate Strength Lbs./In.²	% Elongation in 2 In.	Electrical Conductivity % Annealed Copper Standard
8	Barium	0.10	0.06	61,100	5.0	98.2	35,300	32.5	100.8
9	Barium	0.17	0.08	57,000	4.5	99.3	34,600	34.0	101.8
10*	Barium	0.50	0.04	....	...	97.5	....	..	100.2
11*	Barium	3.0	Trace	....	...	100.8	....	..	101.9
12	Strontium	0.10	0.03	60,800	3.5	99.2	35,000	38.0	101.2
13*	Strontium	0.50	0.04	....	...	97.0	....	..	99.4

*Prepared in fused silica under hydrogen.

shows that, in the case of both barium and strontium, but a small quantity of the added element remained in the copper. This condition occurred even in melts prepared under hydrogen, in which the possibility of oxidation of barium and strontium was reduced to a minimum. These results indicate a small tendency, if any, for these elements to alloy with the copper.

The mechanical properties of the hard drawn and annealed wire are, in both cases, not much different from those of tough pitch copper. The conductivities in the two conditions are generally high. This would be expected in view of the fact that very little of the added element remained in the copper. In the three melts prepared under conditions permitting oxidation of the copper during melting, satisfactory deoxidation with both barium and strontium was obtained. This is evident from the results in Table 3 which show the copper to have high ductility and strength after annealing in hydrogen.

Table 3
Data which Show the Effectiveness of Barium and Strontium as Deoxidizers in Copper
Annealed 1 Hr.–800° C in H_2

Melt No.	Deoxidizer Added	Ultimate Strength Lbs./In.²	% Elong. in 2 In.	Electrical Conductivity % Annealed Copper Standard
8	Barium	34,000	37.5	100.0
9	Barium	33,300	36	101.8
12	Strontium	34,200	38.2	101.0

The Properties of Copper Deoxidized with Lithium

The use of lithium in the deoxidation of copper has been described by Masing and Haase.[3] Their experience indicates that precautions and care are requisite if satisfactory results are to be obtained. The difficulties encountered were apparently due to the exceeding rapidity with which the lithium diffused through the copper and combined with the oxygen of the air. This resulted in pitted surfaces on the castings.

In the investigation reported in this paper, it was observed that lithium is exceedingly reactive with the oxides ordinarily present in refractories. For example, in the case of one melt prepared in an alundum lined crucible a low conductivity was obtained. An analysis of the material showed the presence of an appreciable amount of aluminum and silicon. A similar result was obtained in the case of alloy 15 as shown in Table 4. This alloy which had been prepared in a fused silica crucible contained an appreciable percentage of silicon. These facts indicate that lithium is active in reducing what are ordinarily considered refractory oxides and for this reason has definite limitations in deoxidizing copper, if high conductivity is a necessary property of the final material.

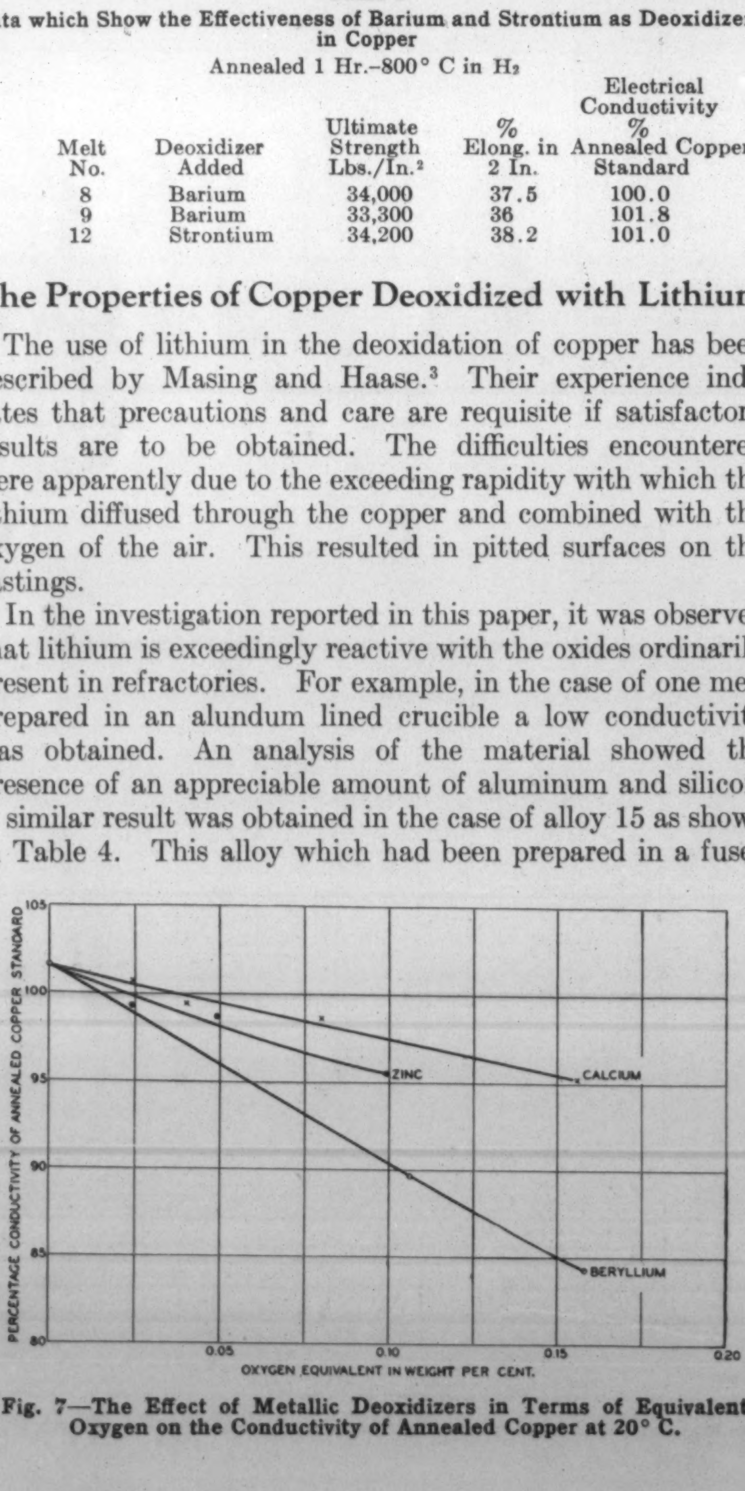

Fig. 7—The Effect of Metallic Deoxidizers in Terms of Equivalent Oxygen on the Conductivity of Annealed Copper at 20° C.

Table 4
The Properties of Copper Deoxidized with Lithium

			Hard Drawn			Annealed 1 Hr. 800° C. in Air		
Melt No.	% Lithium Added	% Lithium by Analysis	Ultimate Strength Lbs /In.²	% Elong. in 2 In.	Electrical Conductivity % Annealed Copper Standard	Ultimate Strength Lbs./In.²	% Elong. in 2 In.	Electrical Conductivity % Annealed Copper Standard
14	0.08	0.04	59,000	3.1	77.0	34,300	30	83.0
15	0.13	0.03	58,000	4.7	94.6	35,300	33	96.1

The results given in Table 4 indicate that copper deoxidized with lithium has good mechanical properties. If precautions are taken to prevent refractory contamination, the conductivity is satisfactorily high. The deoxidation was complete as shown in Table 5.

Table 5
Data Which Show the Effectiveness of Lithium as a Deoxidizer in Copper
Annealed 1 Hr.–800°C in H_2

Melt No.	Ultimate Strength Lbs./In.²	% Elong. in 2 In.	Electrical Conductivity % Annealed Copper Standard
14	35,600	30.0	79
15	35,800	32.0	97

Comparison of Effects of the Several Deoxidizers in Copper

The use of metallic deoxidizers, as was pointed out in the earlier paper, has a disadvantage in that the excess metal in most cases alloys with the copper and results, in general, to diminish the conductivity. To reduce this effect to a minimum it is necessary to know within close limits the oxygen content of the copper prior to deoxidation.

The effect of the deoxidizers calcium, zinc and beryllium expressed in terms of equivalent oxygen are plotted in Fig. 7. The curves show that calcium is somewhat superior to either zinc or beryllium in regard to the effect of the residual deoxidizer on the electrical conductivity.

Both barium and strontium are satisfactory deoxidizers for copper. In addition these elements appear to have a very limited solubility in copper and therefore decrease the conductivity but little. It is doubtful if at the present time either of these elements could be used commercially on account of the high cost.

Lithium satisfactorily deoxidizes copper, but has definite limitations in that it combines rapidly with the oxygen of the air and reduces some refractory oxides.

References

[1] Earle E. Schumacher, W. C. Ellis & John F. Eckel, Deoxidation of Copper with Calcium and Properties of Some Copper-Calcium Alloys. *American Institute of Mining & Metallurgical Engineers, Technical Publication*, No. 240.

[2] Mathiessen. *Annalen der Physik* (*Poggendorf's*), Vol. 110 (1860), Haas. *Annalen der Physik* (*Wiedmann's*), Vol. 52 (1849), page 673. Puschin & Rjaschaky. *Zeitschrift für anorganische Chemie*, Vol. 82 (1913), page 53.

[3] Masing & Haase, Herstellung von Kupferguss mit höher Electrischer Leitfähigheit. *Wissenschaftliche Veröffentlichungen aus dem Siemens-Konzern*, Vol. 7 (1928), page 321.

The New Research Laboratory of the Aluminum Company of America

By Richard Rimbach*

> *Improved alloys and improved metallurgical plant practice come primarily from the brains that are applied to metallurgical research. To use research brains to best advantage, the hands those brains direct must have suitable apparatus to use, suitable environment—which is as much psychological as physical—must be provided if research is to produce results.*
>
> *The physical environment of the workers, the arrangement of the laboratories and the type of equipment used, will vary with the nature of the research work, but a trip through any up-to-date laboratory will give useful ideas to workers in other lines.*
>
> *From time to time, we shall give our readers descriptions of various modern research laboratories. This article is the first of the series.*

A little over a year ago, the Aluminum Company of America purchased a 14-acre farm on the crest of a hill on the outskirts of New Kensington. To-day there stands in the center of this tract a building 275 feet long with 108-foot wings at each end housing the research laboratory. The building surrounded by landscaped lawns commands a sweeping view of the Allegheny River and the nearby foot-hills of the Allegheny Mountains. The building doubtless is the most completely aluminized structure ever erected and demonstrates the extent to which aluminum can be adopted as a structural and decorative metal for architectural purposes. The grounds are surrounded with an aluminum alloy wire fence and the entrance is through a hand-wrought gate of aluminum.

At the main entrance to the building are aluminum doors with cast aluminum grille work, framed by aluminum alloy castings on which ornamentation of colored glaze in blues, greens and weathered metal effects has been applied. On the exterior are window frames, spandrels, mullions, copings and ornamental trim of aluminum alloys, while surmounting the building is a decorative multicolor aluminum cornice. In the lobby, aluminum strips in the terrazzo floor harmonize in design with aluminum wall fixtures, chandeliers and radiator grille work. The elevator doors are executed in repoussé by hand-hammering of aluminum sheets.

The elevator is of aluminum alloy construction. Stairways have aluminum balustrades, newel posts and treads, while the substructure is finished with aluminum paint. Office radiators are covered with ornamental aluminum casings, window frames are heat-treated aluminum alloy, and door fittings and other hardware are likewise of aluminum.

Aluminum chairs are found in the offices, and benches, balance cases and other equipment in the laboratory are of the same metal. A cafeteria with aluminum tables and chairs is located on the ground floor. Extensive use has been made of aluminum in the kitchen equipment. Many companies have cooperated in these first installations, so that others desiring to imitate this construction will find commercial agencies ready to serve them.

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* Associate Editor.

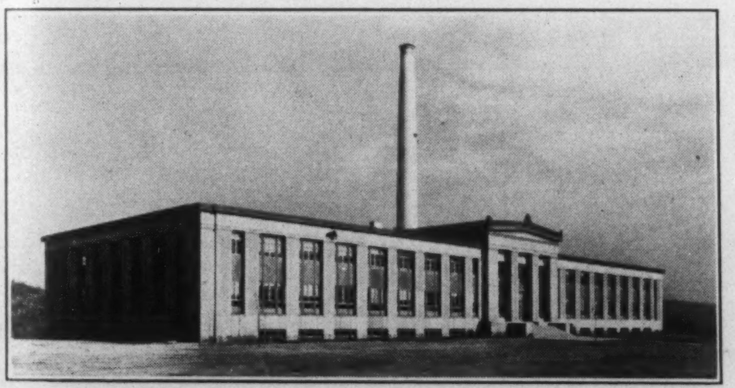

Fig. 1—Front View of Aluminum Research Laboratories

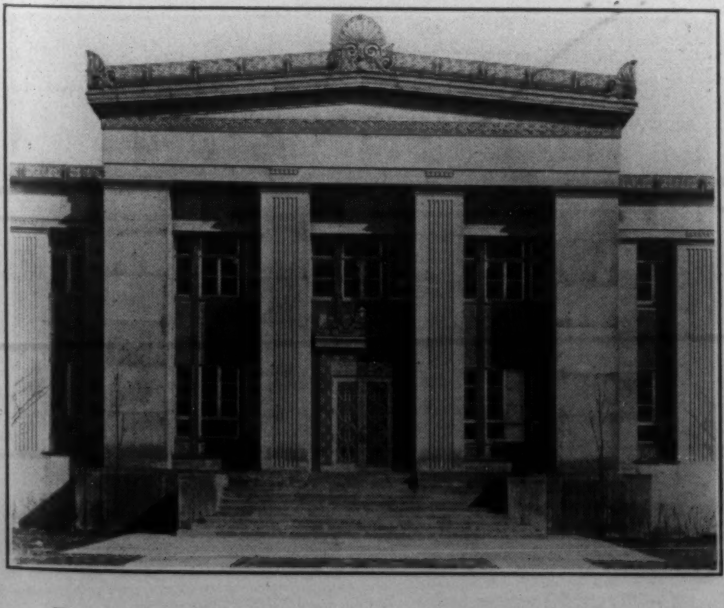

Fig. 2—Front Entrance to Aluminum Research Laboratories

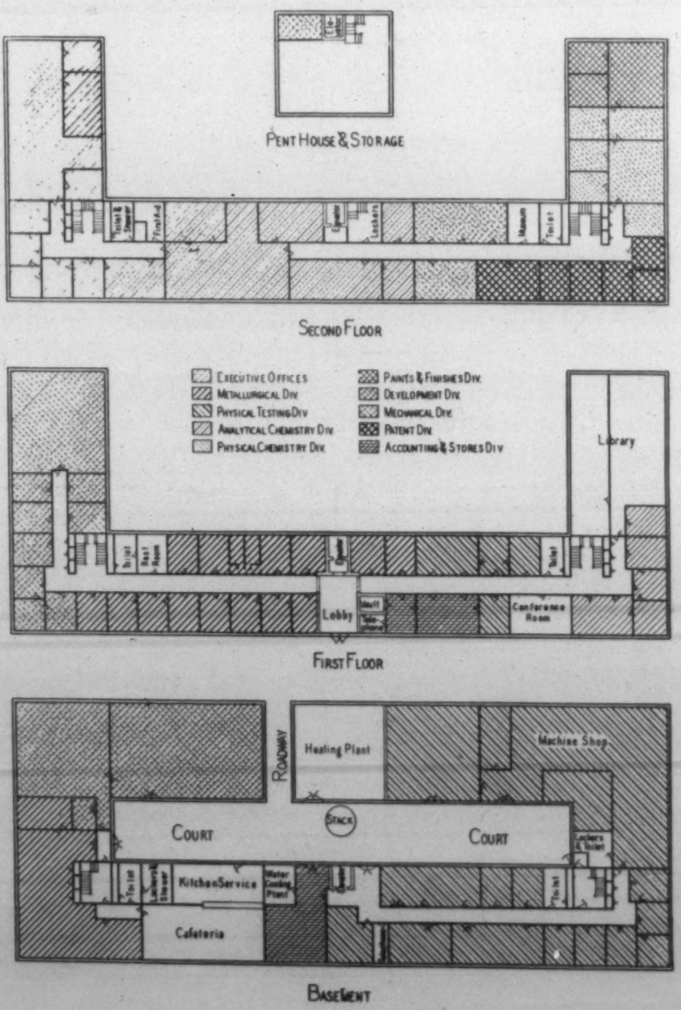
Pent House & Storage
Toilet & Shower
First Aid
Elevator
Lockers
Museum
Toilet
Second Floor
Executive Offices
Metallurgical Div.
Physical Testing Div.
Analytical Chemistry Div.
Physical Chemistry Div.
Paints & Finishes Div.
Development Div.
Mechanical Div.
Patent Div.
Accounting & Stores Div.
Library
Toilet
Rest Room
Toilet
Lobby
Vault
Telephone
Conference Room
First Floor
Roadway
Heating Plant
Machine Shop
Stack
Court
Court
Lockers & Toilet
Toilet
Lockers & Shower
Kitchen Service
Water Cooling Plant
Toilet
Cafeteria
Basement

Fig. 3—Floor Plan

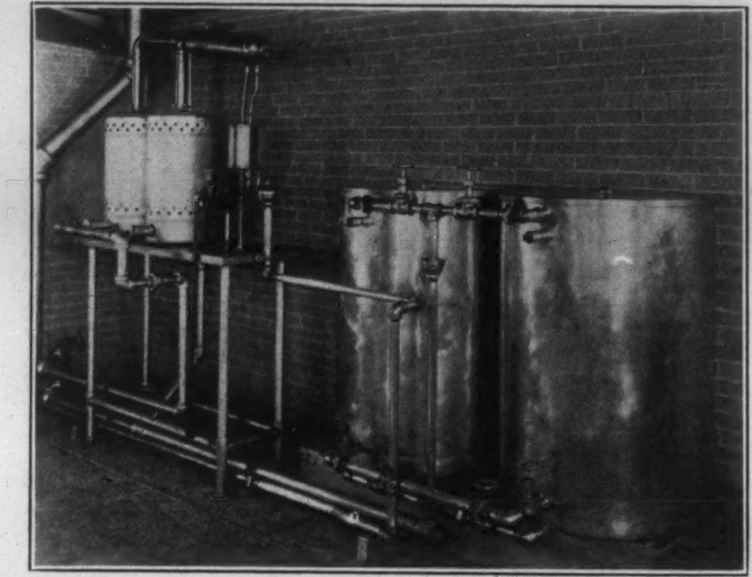

Fig. 4—Equipment for Production and Storage of Distilled Water, Aluminum Tanks Each Hold 120 Gallons; Fittings Are All Aluminum and Distilled Water Is Distributed through Aluminum Pipe Line

The hot and cold water system for the entire building is of aluminum pipe, but more significant is the storage and distribution of the distilled water in aluminum. This installation is based on 12 years of satisfactory experience in handling distilled water in aluminum.

The work of the Aluminum Research Laboratories is handled by a number of divisions:

The *Metallurgical Division* works on the development of new alloy compositions and processes as well as on the perfection of old alloy compositions and processes. Equipment for experimental melting, casting and rolling of aluminum alloys is located on the ground floor. Heat treatment is becoming increasingly important with the advent of the strong aluminum alloys, and a variety of types of electrically-heated furnaces are provided for this purpose. The metallographic investigation of aluminum alloys also frequently requires long-time heat treatments in order to produce structural equilibrium. Smaller furnaces, with accurate temperature control maintaining constant temperatures for periods of several months, are used for these experiments. To hold the specimen temperatures constant in spite of slight fluctuations in the furnace temperature, the specimens are placed in holes drilled in a block of aluminum, which almost fills the furnace. By a system of compensating thermocouple lead wires, the temperature of any furnace may be accurately ascertained by means of a centrally located precision potentiometer. Aluminum paint on the furnace equipment decreases radiation losses and adds to the lighting efficiency of the laboratory.

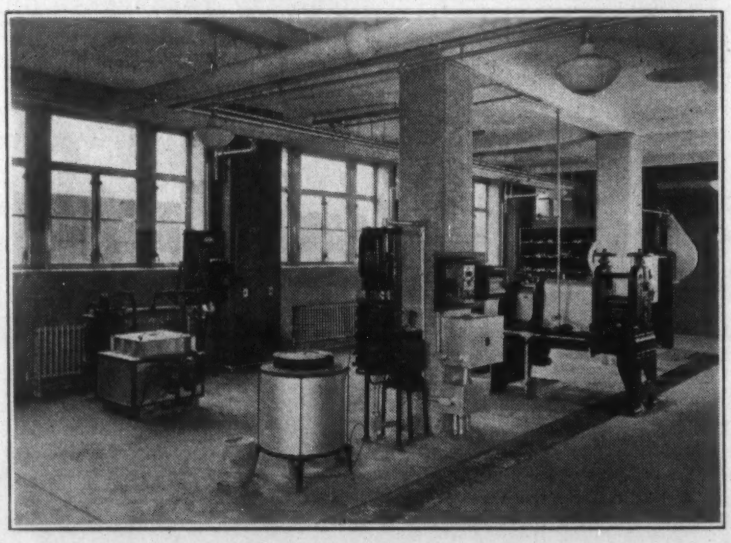

Fig. 5—Metallurgical Laboratory Showing Furnaces and Rolls for Experimental Production of Aluminum Sheets

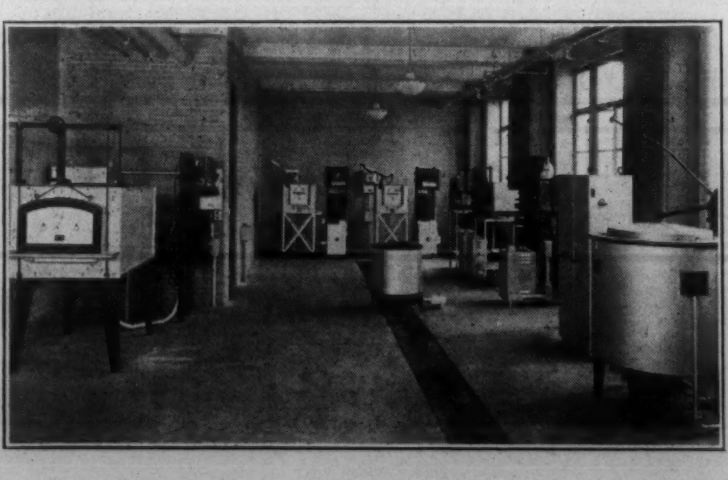

Fig. 6—Metallurgical Laboratory, Showing Furnace Equipment for Annealing, Preheating, and Heat Treatment of Aluminum and Its Alloys

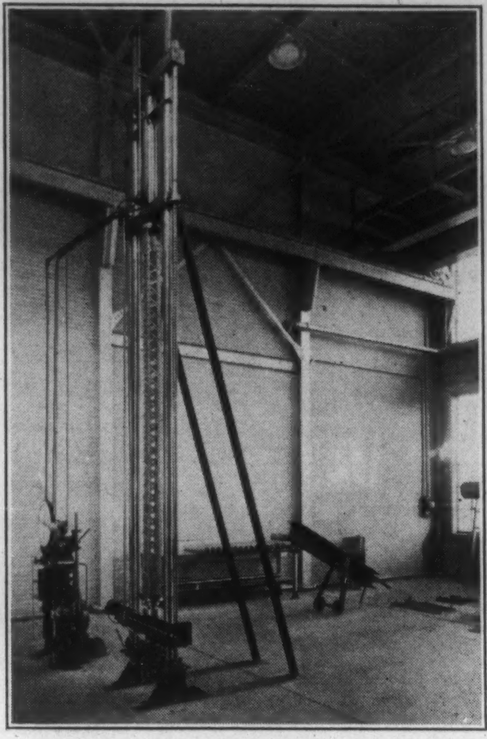

Fig. 7—Amsler Testing Machine (40,000 Pounds' Capacity) with Aluminum Alloy Structural Member in Position for Test; End of Aluminum Crane Seen in Right Upper Corner of Photograph

Microscopic examination is an important tool of metallurgical research. The preparation of a metal sample includes a surfacing operation with a microtome, followed by wet polishing on broadcloth-covered wheels. Zeiss microscopes are used for visual examination of specimens as well as for photomicrography of structures of special interest. These instruments are capable of magnification as low as 5 diameters and as high as 16,000. Two metallurgical laboratories are also equipped for investigating the relative corrosion resistance of aluminum alloys, as well as other metals.

The *Physical Testing Division* determines the physical properties and studies related engineering problems. The

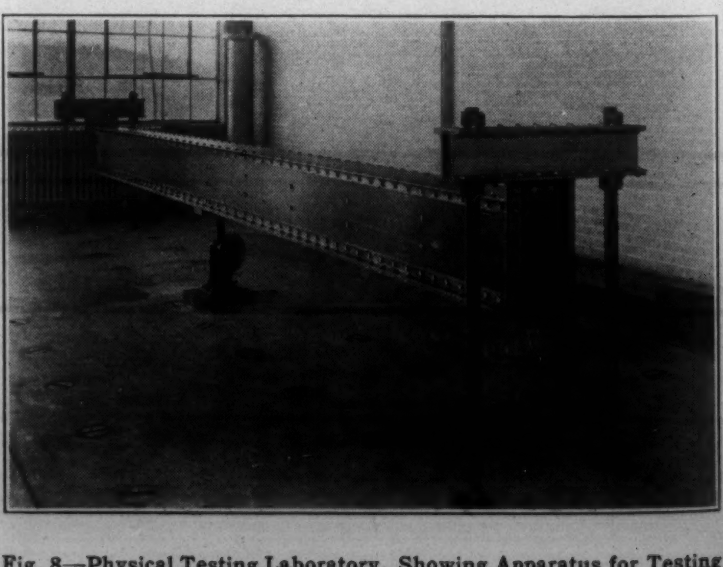

Fig. 8—Physical Testing Laboratory, Showing Apparatus for Testing Structural Beams of Aluminum Alloy

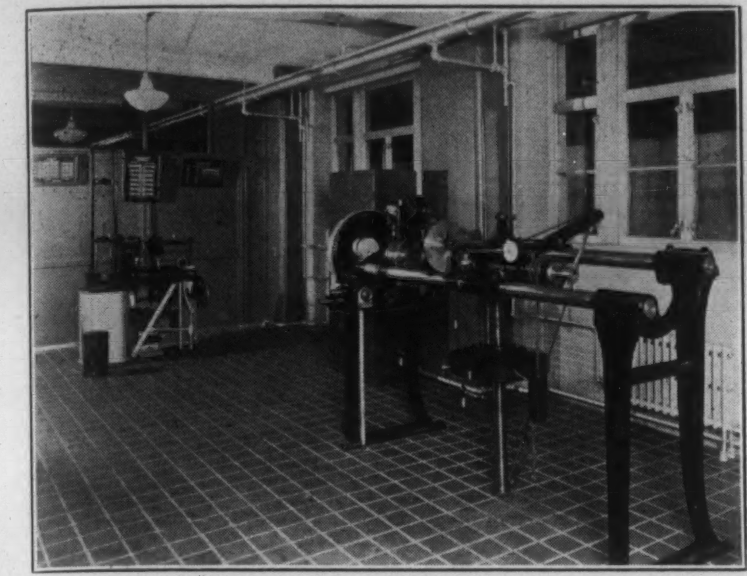

Fig. 9—Amsler Torsion Testing Machine in Foreground. In Background Small Universal Testing Machine

laboratories of this division are exceptionally well equipped with testing equipment for the accurate determination of the mechanical properties of metals as well as the strength of fabricated units and structures. The equipment includes a 300,000-lb. Amsler hydraulic testing machine, taking tension and compression specimens up to 10 feet in length, or beams with a maximum span of 10 feet. A somewhat smaller machine has capacities ranging up to 40,000 pounds. These machines are served by a 3-ton aluminum alloy crane.

Adjacent to these large machines is a universal floor test slab consisting essentially of a reinforced concrete beam 12 feet by 30 feet, the upper surface flush with the floor. In this beam are 48 inserts, each capable of withstanding a pull of 25 tons. By the use of suitable tension bolts and cross members, accurately calibrated hydraulic jacks with capacities up to 75 tons may be used in testing girders, trusses, car frames, truck frames and large machine parts.

An Amsler torsion testing machine has capacities ranging from 240–1200 foot-pounds, and handles specimens having a maximum diameter of $3^1/_4$ inches, and lengths up to 4 feet. Smaller universal testing machines include two Amsler machines, each having seven capacity ranges of 200–20,000 pounds, and two Olsen wire testing machines each having capacities of 1,000–10,000 pounds. Provision is made for making tensile tests of metals at both high and low temperatures over a range of −112° F. to +1200° F. Equipment is also provided for the calibration of extensometers and caliper testing devices, as well as the calibration of other testing machines. A thoroughly modern machine shop is located on the ground floor of the building. Here equipment and apparatus for the laboratories are constructed and repaired, and the test specimens required are prepared on a production scale.

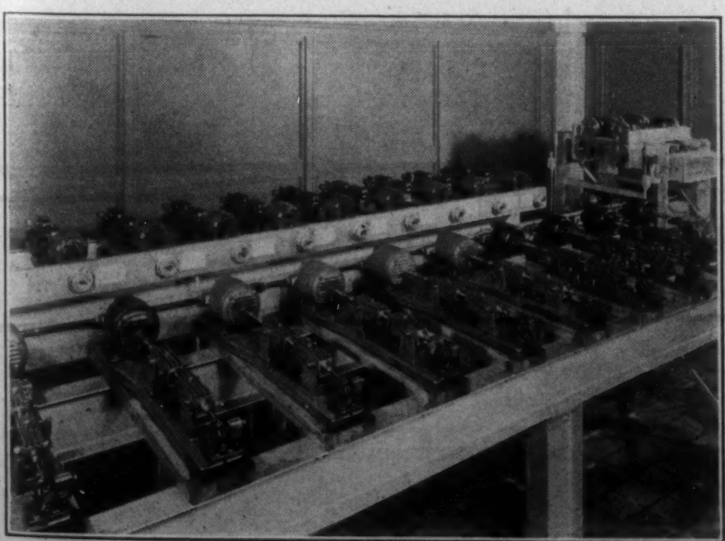

Fig. 10—Machines for Determining Endurance Limit or Fatigue Strength of Aluminum and Its Alloys

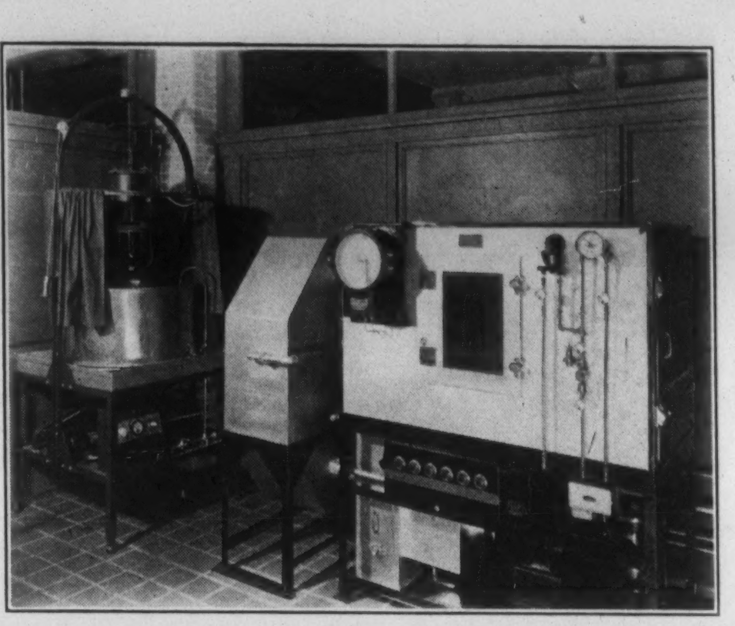

Fig. 11—Equipment (Left) for Accelerated Weathering of Paints and Finishes, with Controlled Humidity Cabinet at the Right

Testing machines are provided for the determination of the fatigue properties of metals. This equipment includes 20 Moore rotating-beam machines, 8 constant deflection-constant stress fatigue machines for testing sheet metal, 4 direct tension fatigue testing machines and one cantilever specimen type machine arranged for testing aluminum tubing and fittings.

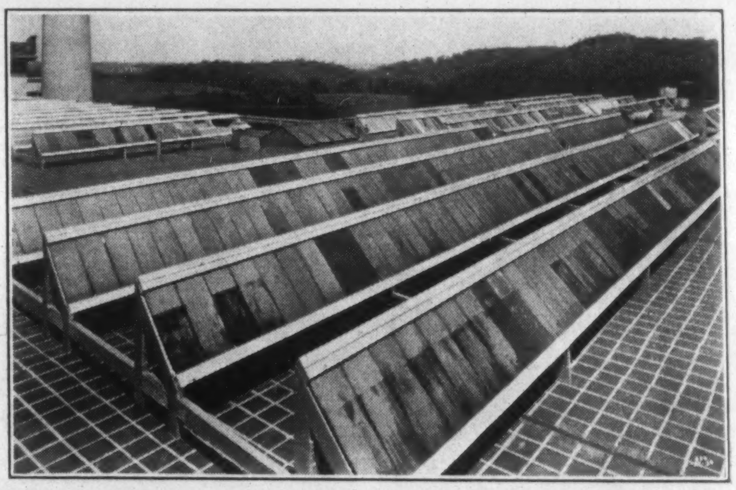

Fig. 12—Paint Test Racks on Top of Aluminum Research Laboratories Used to Determine the Durability of Other Paints in Comparison with Aluminum Paint

The *Physical Chemistry Division* handles precise measurements of a physical nature. For the attainment of very high temperatures, a 15 KVA high-frequency induction furnace is available in this laboratory. With this furnace, high temperature experiments can be carried out *in vacuo* and temperatures as high as 5400° F. are readily attainable.

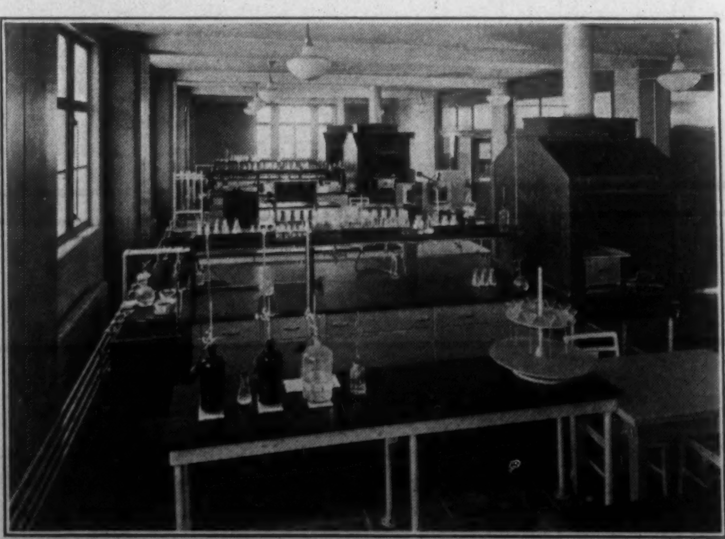

Fig. 13—General View of Chemical Laboratory for Metal Analysis. Some Applications of Aluminum in Laboratory Equipment Are Here Shown as Benches, Tables, Hood Supports, Filter Racks, Hotplates, Chairs, Water Piping, Valves and Fittings, Drawer Pulls and Hinges

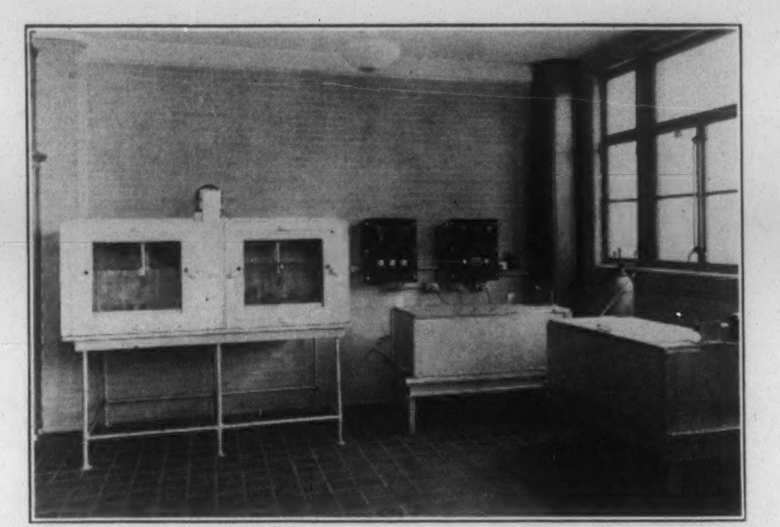

Fig. 14—Laboratory for Accelerated Corrosion Tests on Metals and Alloys

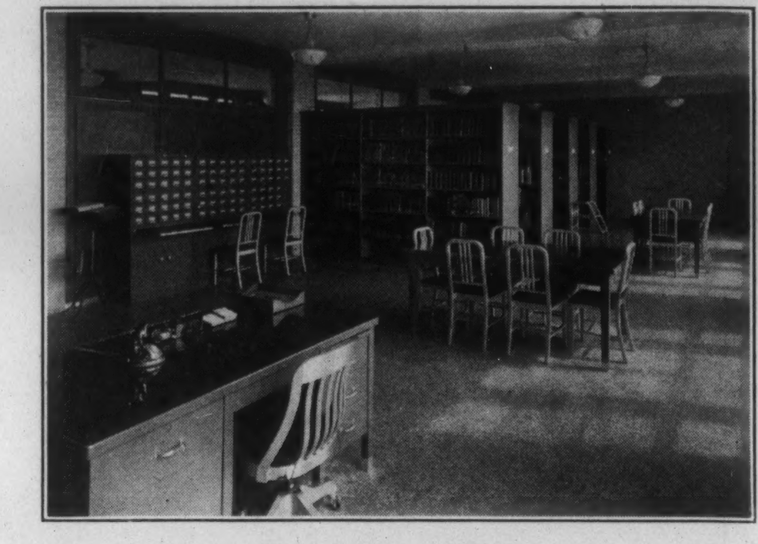

Fig. 15—View of Library

This division is equipped to make precise measurements of such varied properties of materials as conductivity, density of solid and liquid metals, melting point, solubility of gases in liquid metals, density and electrical conductivity of solid metals includes a constant-temperature oil bath containing a resistance bridge, a standard resistance and precision potentiometer and galvanometer with a sensitivity of one hundred-millionth of a volt.

The *Paints and Finishes Division* studies the problems connected with aluminum paint and with the application of other paints and finishes to aluminum surfaces. For accelerated testing of paints and finishes a special ultraviolet light is used with water spray conveniently attached, so that artificial weather, including sunshine, summer heat, rain and (in a separate electric refrigerator) winter cold, are available at all times. For determining the moisture-proofing properties of paint coatings, a cabinet with controlled temperature and humidity is employed. On the roof of the laboratories, exposure racks provide space for more than 1,000 test panels of wood or metals, as well as for aluminum samples to check the accelerated corrosion tests made by the *Analytical Chemistry Division*.

The *Analytical Chemistry Division* investigates and establishes standard analytical methods for the company's 17 plant laboratories; studies the chemical or corrosion behavior of aluminum in various industrial uses, and renders assistance to the *Sales Department* on problems involving chemical behavior of the metal. The several laboratories of this division are located on the top floor of the building, which permits the installation of equipment for the effective removal of chemical fumes.

The *Chemical Development Division* handles both small- and large-scale problems of a chemical nature relating to the production of alumina and other chemical problems and by-products. In these laboratories are a variety of ovens; gas-fired and electric furnaces; pressure digesters; crushing, grinding and pulverizing machinery; sieves and classifiers.

The *Mechanical Division* devotes its time to machine development. The *Patent Division* secures and classifies every patent, both foreign and domestic, which appears to be of interest in connection with the company's operations. To keep the laboratory staff fully informed of the latest developments, an extensive *Library* is available. The card index in the library contains some 75,000 cards covering books, scientific articles and technical correspondence on subjects of interest to the laboratories. In a separate workroom in the library, the technical correspondence is filed according to subject matter.

Twelfth Annual Metal Congress

Technical programs of the twelfth annual National Metal Congress to be held in Chicago the week of September 22, are assuming final form, according to information received from W. H. Eisenman, director of the Congress and Exposition and secretary of the American Society for Steel Treating.

Meeting with the steel treaters at the 1930 Congress will be the Institute of Metals and the Iron and Steel Division of the American Institute of Mining and Metallurgical Engineers, the Machine Shop Practice and the Iron and Steel Divisions of the American Society for Mechanical Engineers, and the American Welding Society.

The American Society for Steel Treating has scheduled sessions on sales problems, corrosion-resisting metals, nitriding, forgings, steel melting and carburizing. Two other sessions will be devoted to miscellaneous topics and a third to papers dealing with theoretical metallurgy. The Campbell Memorial Lecture, to be delivered by M. A. Grossmann, vice-president of the Republic Research Corp., will be on "Oxygen in Steel."

The American Institute of Mining and Metallurgical Engineers will sponsor two sessions on the beneficiation of iron ore. These will be lead by C. B. Murray, consulting chemist, Cleveland. The rest of its program is divided into a well-rounded program of papers dealing with ferrous and nonferrous topics.

A session on combustion problems and furnace design is a high light of the American Society for Mechanical Engineers program The molding of phenol materials will be discussed in detail at another session. Polishing and nitriding are also on the program.

The Welding Society has scheduled a session on the welding of structural steel which is expected to draw a large attendance. Reports of recent researches into welding procedure will be presented at the other American Welding Society meetings.

Calendar of Meetings

International Exposition at Liége, Belgium, Chemical and Engineering Session, Sept. 14–21.

Iron and Steel Institute (British), Prague, Sept. 15–20, 1930.

Société dé Chimie Industrielle, Liége, Belgium, Sept. 21–27.

National Metal Congress and Exposition, Hotel Stevens, Chicago, Ill., Sept. 22–27.

American Society for Steel Treating, Annual Convention, Chicago, Ill., Sept. 22–27.

Institute of Metals Division of American Institute of Mining and Metallurgical Engineers, Annual Fall Meeting, Chicago, Ill., Sept. 22–27.

Iron and Steel Division of American Institute of Mining and Metallurgical Engineers, Annual Fall Meeting, Chicago, Ill., Sept. 22–27.

Iron and Steel Division, Machine Shop Practice Division American Society of Mechanical Engineers, Annual Fall Meeting, Chicago, Ill., Sept. 22–27.

American Welding Society, Annual Fall Meeting, Congress Hotel, Chicago, Ill., Sept. 22–27.

American Electrochemical Society, Hotel Statler, Detroit, Mich., Sept. 25–27, 1930.

British Cast Iron Research Association, London, England, Oct. 29.

American Gas Association, Atlantic City, N. J., Oct. 13–17.

American Petroleum Institute, Chicago, Ill., Nov. 10–13, 1930.

American Institute of Chemical Engineers, New Orleans, La., Dec. 8–10, 1930.

Association for the Advancement of Science, Cleveland, Ohio, Dec. 29–Jan. 31, 1931.

The Driver-Harris Company, Harrison, N. J. has been granted a melting license by the Krupp-Nirosta Co., Watervliet, N. Y., for the production of Nirosta Steel in the form of castings, rods, sheet, strip and wire.

The Heat Treatment of Aluminum Alloys[†]

By Robert J. Anderson[*]

The value of a firm foundation of metallurgical science as a basis for practical processes is nowhere more evident than in the heat treatment of aluminum alloys. This is one case where no one can question the fact that successful practice is founded on sound theory. That the theory, even if not complete in every detail, is an effective working tool is due to the vast amount of high grade scientific effort put on it.

So voluminous are the publications on the subject that a résumé such as this will save time for those who wish either to get an introduction to the subject or to brush up on it.

Introduction

The development of heat-treatment processes (and of alloys especially susceptible to heat treatment) constitutes one of the most important innovations in the history of aluminum metallurgy. By heat treatment is meant here the combination of quenching and aging that causes marked enhancement of mechanical properties. Heat treatment has been the most potent factor in widening the market for aluminum-alloy manufactures, both cast and wrought. Viewed more broadly, the theoretical and scientific investigations that have been carried out for the purpose of explaining the phenomena involved in quenching and aging have had far-reaching effects in the entire domain of physical metallurgy. More specifically, studies made to determine the reason for the mysterious hardening-on-aging of duralumin laid the foundation for an entirely new conception of alloys. Mercia's theory, advanced in 1919, soon led to the conclusion that heat treatment, or rather hardening on quenching or on quenching followed by aging, is based on physico-metallurgical phenomena which are common to alloys in general. Consequently, an entirely new alloy metallurgy has been developed in the past ten years, and the former sharp line of demarcation between ferrous and non-ferrous alloys has ceased to exist.

The commercial value of systematic research has nowhere been more strikingly demonstrated than in the heat treatment of the light aluminum alloys. Lack of a working metallography had long been a deterrent to the development of many engineering uses of aluminum alloys. Singular to say, despite all that has been done in this and allied fields, such "abstruse" matters as constitutional diagrams are still being decried in some quarters of the metal industry as something far-fetched and nebulous. In passing, it should be pointed out that the preparation of *pure* aluminum by the Hoopes process has been of prime importance in developing the rationale of heat treatment. The availability of pure aluminum has enabled metallographers to study the effects of impurities and construct accurate constitutional diagrams.

Prior to the introduction of heat-treatment processes, the utilization of wrought and cast aluminum-alloy products was very considerably restricted because of their relatively poor mechanical properties. Millions of dollars worth of sales were lost by the aluminum industry in the period 1910 to 1920 primarily because the metallography of aluminum had not been currently developed to a science ranking with that of steel. This situation has happily been corrected, and at the present time research activity in the field of aluminum physical metallurgy is very pronounced. It is significant to the future business welfare of many diverse branches of the metal industry that the heat treatment of aluminum alloys is here to stay. This development has already resulted in radical departures in casting and fabricating methods, has opened up new markets for light alloy manufactures, and finally has been the direct cause for the increasing severity of competition among structural materials. Heat-treated aluminum alloys are displacing old and hitherto firmly established materials in many engineering applications.

Theoretical Aspects of Heat Treatment

The more theoretical aspects of aluminum-alloy heat treatment have been almost done to death in a long list of papers published in recent years. Hence, no comprehensive discussion of the subject is contemplated here. It is necessary, however, to give a brief statement of the underlying principles so that the methods of plant practice may be understood and appreciated. Until recently, the precipitation theory had satisfactorily explained all the phenomena taking place on aging after quenching with the exception of the change in the electrical resistivity of duralumin. Some recent work appears to reconcile this apparent anomaly with the general theory.

Broadly speaking, the properties of any alloy, that undergoes a solid transformation or an eutectoid change or in which the solid solubility of one constituent (the solute) in another (the solvent) is altered appreciably by raising the temperature, can be changed by quenching alone from a suitable elevated temperature or by quenching followed by aging. There are cases in which eutectoid changes or some other transformation are operative in altering the properties of aluminum alloys. These are not met with, however, in commercial compositions and will not be considered here. The present generally accepted explanation for the hardening and strengthening of aluminum alloys on quenching followed by aging may be summed up as follows:

(1) The alloying constituents that cause hardening form solid solutions with aluminum to considerable but still limited percentages.

(2) The solid solubility increases markedly with increase in temperature.

(3) On quenching from an elevated temperature, the solid solution becomes supersaturated with respect to the ordinary temperature.

(4) On aging, there is precipitation of the dissolved substance.

(5) Precipitation is the direct cause of the alteration in properties.

(6) Aging consists in allowing the quenched alloy to stand at a suitable temperature and for a sufficient period of time to effect the desired precipitation.

Figs. 1 and 2 show the partial constitutional diagrams of the aluminum–copper and aluminum–magnesium silicide systems, respectively, at the aluminum ends. In these figures, the line *EC* traces the variable solubility with temperature. Alloys in equilibrium to the left of *E* are not heat treatable. If any alloy of composition between *E* and the abscissa of *C* is heated to a temperature just above that temperature corresponding to the juncture of the composition ordinate and *EC*, then that alloy will dissolve all the excess substance. Thus, taking the composition 96:4 aluminum-copper; as cast and at the ordinary temperature, this alloy consists of a solid solution plus excess $CuAl_2$. On heating to 500° C. for a sufficiently long time, the entire 4% copper goes into solid solution. With the excess substance in solid solution, if the alloy is then quenched from

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[†] In two parts, Part I, Part II will be published in October.

[*] Consulting Metallurgical Engineer, Cleveland, Ohio.

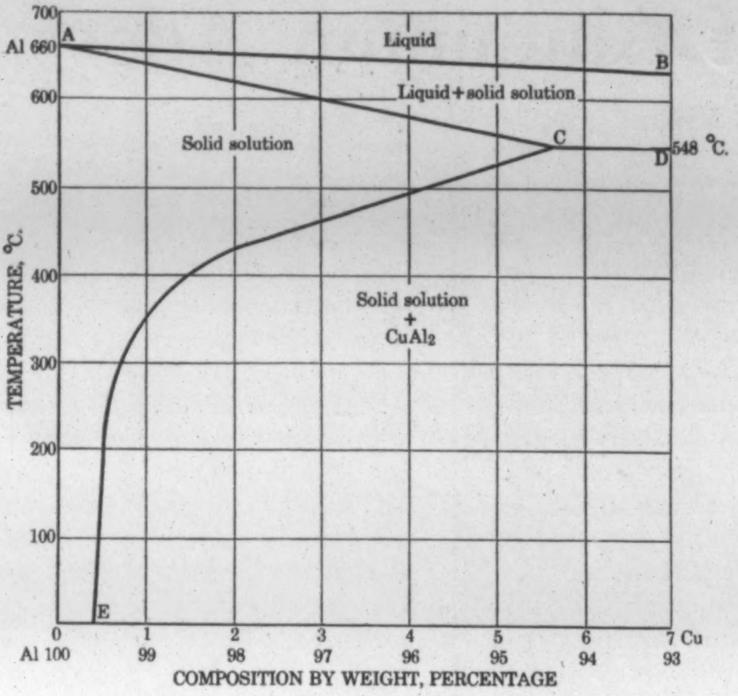

Fig. 1—Partial Constitutional Diagram of the Aluminum–Copper System (Redrawn from Data of Dix and Others)

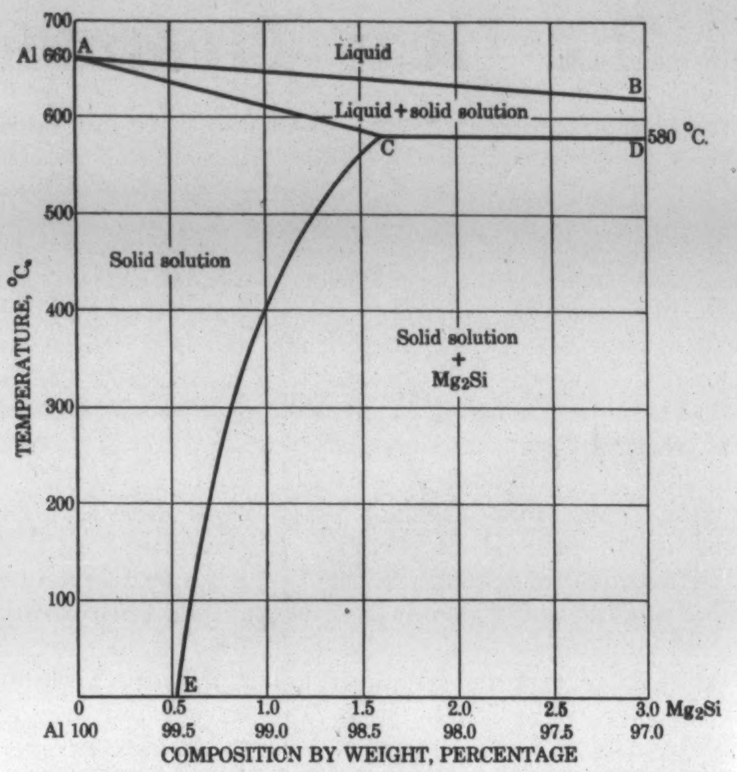

Fig. 2—Partial Equilibrium Diagram of the Aluminum–Magnesium Silicide System (Redrawn from Data of Hanson and Gayler)

the elevated temperature, there is preserved at the ordinary temperature (or some low temperature) a solid solution supersaturated with solute in respect to the low temperature. The alloy so quenched will set free the substance dissolved (in excess of the equilibrium solubility) at some temperature by precipitating it in minute particles. This precipitation is called the aging effect and is accompanied by increase in elastic limit, strength and hardness, and by changes in other properties. If aging is sufficiently prolonged at certain temperatures, the original hardening is followed by softening due to coagulation of the precipitate. Hence, some metallurgists believe that maximum hardness (or strength) corresponds to a certain critical size of the precipitated particles.

Referring again to the figures, alloys of percentage composition to the right of the abscissa of *C*, contain more excess substance than can be taken into solid solution by heating at any temperature (below the eutectic horizontal *CD*). Hence, in the heat treatment of alloys of this type, practical operation calls for heating parts to as high a temperature as possible short of incipient melting or deformation. The constitutional changes are quite simple in the binary aluminum–copper or pseudo–binary aluminum–magnesium silicide systems. In polynary alloys, the constitutional changes due to inter-solubility relations may be, and often are, exceedingly complex. Hence, it is not surprising that the mechanical properties obtained on heat treatment are likely to vary considerably with relatively small changes in the composition of complex alloys. As indicated in Fig. 1, about 4% copper is soluble in aluminum at 500° C. When about 0.7% magnesium silicide is added, the solubility of copper is reduced to about 2% at this temperature. On the other hand, in the presence of 2% nickel, about 6% copper is soluble at 500° C. In general, the individual solubility of a given constituent is markedly affected by the simultaneous presence of a second constituent and by the nature of the solid solution. The solid solubility of many metals in aluminum as affected by temperature has been thoroughly investigated, and some of the inter-solubility relations in complex alloys have been studied.

Reverting to the question of precipitation on aging; the setting free of the dissolved excess substance may take place at the ordinary temperature (or below) or at some slightly elevated temperature. Fortuitously, very satisfactory precipitation occurs with quenched duralumin on standing for a few days at the ordinary temperature. If freshly quenched duralumin is maintained in liquid air (−192° C. and below), precipitation will not proceed. Precipitation is very slow or inappreciable with some aluminum alloys at room temperature but takes place satisfactorily only at some elevated temperature, e. g., 100 to 225° C. By suitable control of the precipitation process after quenching, a considerable range of mechanical properties may be secured with given alloys, e. g., high strength with low elongation, fair strength with high elongation or some other combination.

Recent work by Gayler and Preston[1] indicates that precipitation from solid solution entails two processes, viz.: (1) Rejection of the atoms of the dissolved metal from the lattice of the solid solution, accompanied by the possible formation of molecules, and (2) coagulation of the rejected atoms or molecules. These two processes probably overlap. They also find that the parameter of quenched-and-aged duralumin is measurably less than that of the annealed and slowly cooled alloy (this latter being the same as that of aluminum). In other words, the solution of copper in aluminum is attended by a (small) contraction of the aluminum lattice. That this lattice disturbance occurs on precipitation is shown by the broadening of the lines of the X-ray spectrum. Hardness is, therefore, ascribed to the distortion of the space lattice caused by the precipitation of highly dispersed particles. The work of Gayler and Preston tends to confirm Rosenhain's views inferred on theoretical grounds that "the passage of electrons through or between the atoms would be more completely hindered in the decomposed solid solution than it was before such decomposition took place, and, accordingly during the hardening process, so long as the disturbance in the lattice structure increased with further deposition (precipitation) so long would the electrical resistivity increase also." It is accordingly now possible on the basis of experimental data to explain the increase of the electrical resistivity of duralumin on aging.

Microstructure as Affected by Heat Treatment

Heat treatment has profound effect on the microstructure of aluminum alloys, as would be expected. Speaking generally, the microstructure of as-cast alloys of the heat-treatable type consists of the aluminum-rich solid solution and a more or less continuous intergranular network of the alloying constituents. In binary aluminum-copper alloys, the network consists of the intermetallic compound $CuAl_2$, which is hard and brittle. The brittleness (lack of ductility) of the as-cast alloys is properly ascribable to the network. Roughly, the effect of heat treatment is the total or partial elimination or breaking up of the network structure. In the case of wrought alloys, the structure is quite different. Thus, in rolled or forged alloys of the duralumin or magnesium-silicide types, the original network or dendritic structure of the billet has been broken up and destroyed by the working, and the excess substance ($CuAl_2$ or Mg_2Si, or both) is present in the form of small segregate particles. Since in hot-working operations aluminum-alloy wrought products are air quenched, some of the excess substance may be in solid solution. In hot- and cold-worked aluminum alloys, the structure is more or less fragmented and fibrous, and the excess constituents broken up—the final structure depending upon the amount of reduction and the temperature of working. On annealing, the excess substance is precipitated. Wrought and annealed aluminum alloys may contain rather large segregate particles formed by precipitation and coagulation.

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[1] M. L. V. Gayler & G. D. Preston, The Age-Hardening of Some Aluminum Alloys. *Journal Institute of Metals*, Vol. 41 (1929), pages 191–234.

In high-copper alloys of the piston type (10% copper), the network is continuous and is only partly broken up by the solution heat treatment. In low-copper alloys, however, the network is not continuous and may be eliminated or completely broken up. While the hardness and strength of the high-copper alloys may be considerably enhanced by solution and precipitation treatment, not much change can be produced in the elongation because of the large amount of excess substance present. In the low-copper alloys, all, or the great bulk, of the $CuAl_2$ network may be taken into solution so that the hardness strength and elongation may be substantially and simultaneously increased. Of course, in the case of polynary alloys, the network may be very complex and include several constituents. Such constituents are, however, all hard and brittle, and their total elimination (by solid solution) or partial elimination (by solid solution and change of form—e. g., by spheroidization) is the aim of heat treatment. The relation of the network structure and properties and the effect of heat treatment on microstructure in the case of cast alloys have been discussed by Archer and Jeffries,[2] among others.

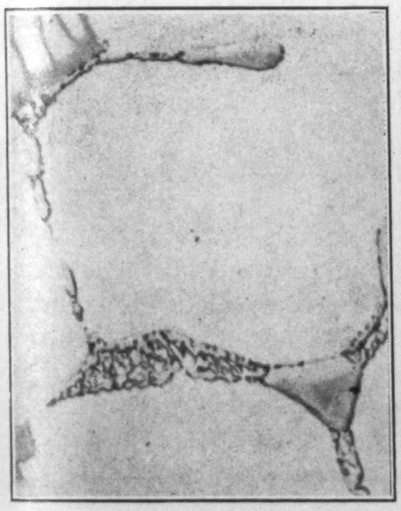

Fig. 3—Filigree and Segregate $CuAl_2$ in Cast Duralumin; Etch HNO_3 Quench; Mag. 1500 ×

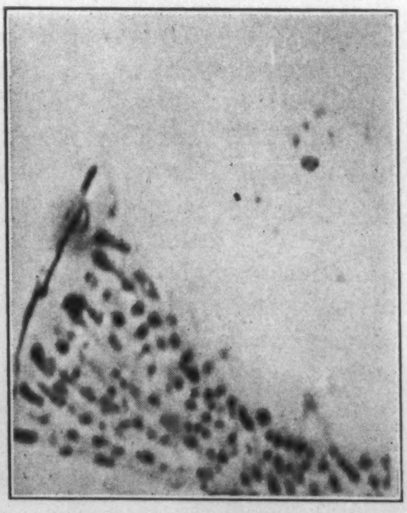

Fig. 4—Filigree of $CuAl_2$ and Mg_2Si in Cast Duralumin; Unetched; Mag. 2000 ×

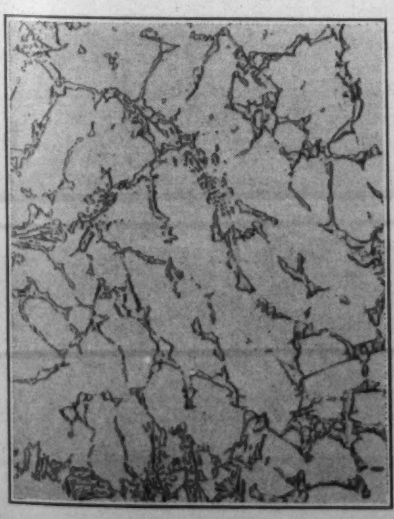

Fig. 5—Average Microstructure of 88.5:10:1.25:0.25 Aluminum-Copper-Iron-Magnesium Alloy as Sand Cast; Unetched; Mag. 100 × (Daniels)

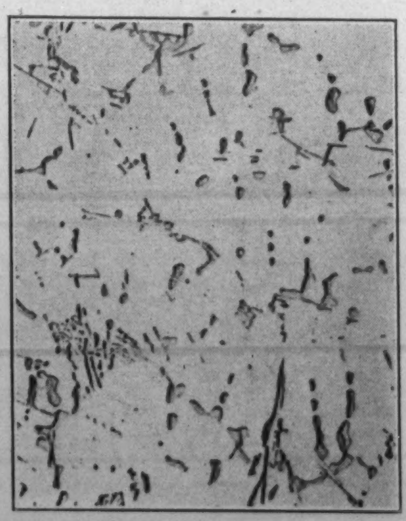

Fig. 6—Average Microstructure of 88.5:10:1.25:0.25 Aluminum-Copper-Iron-Magnesium Alloy, Sand Cast and Heat Treated; Unetched; Mag. 100 × (Daniels)

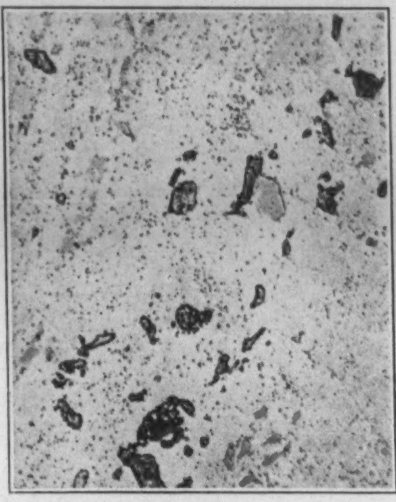

Fig. 7—Average Microstructure of Hot-Rolled Duralumin Slab; Etched HNO_3 Quench; Mag. 200 ×

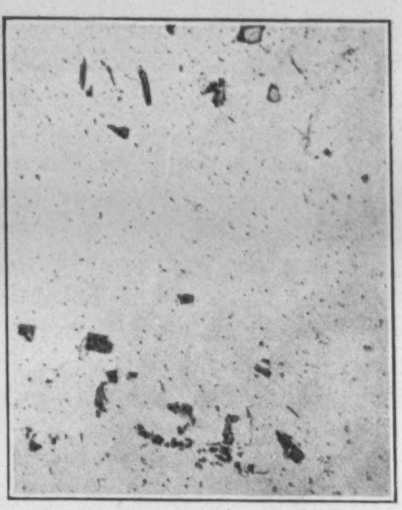

Fig. 8—Average Microstructure of Heat - Treated Duralumin Sheet; Etched HNO_3 Quench; Mag. 200 ×

Some low-copper alloys of the Al-Cu-Mg_2Si type are particularly well adapted to heat treatment in the cast condition. In such alloys, by suitable adjustment of the composition, it is possible to cause most of the $CuAl_2$ and Mg_2Si to occur in the form of a finely divided filigree (probably as a ternary eutectic with the aluminum-rich solid solution). The small particles of the filigree go into solution very much more rapidly than do segregate plates or network structures. Thus, according to Daniels,[3] in alloys of this type, when copper is present in amount over 2% and magnesium is absent or present in amount less than 0.25%, the copper will be found entirely as segregate of massive $CuAl_2$. No filigree will be formed until the magnesium content is sufficient to convert part or all of the silicon into Mg_2Si. In an alloy containing 2% copper and 0.25% silicon, it has been found that nothing but filigree will appear in the microstructure if the magnesium content is 0.45%. Fig. 3 is a micrograph of chillcast duralumin (ordinary composition) showing the $CuAl_2$ present in part as segregate and in part in the form of filigree (with Mg_2Si). Fig. 4 shows a portion of filigree at higher magnification. Further investigation is required to determine just what can be done in promoting the filigration of excess substance in heat-treatable aluminum alloys.

Detailed study has been made by several investigators, notably Daniels (see appended bibliography), of the effect of heat treatment on the microstructure of aluminum alloys. Fig. 5 is a micrograph of the 88.5:10:1.25:0.25 aluminum-copper-iron-magnesium alloy as sand cast, and Fig. 6 shows the structure of the same alloy after heat treatment. The heat treatment consisted in soaking for 96 hours at 497° C., followed by quenching in boiling water and then aging for 16 hours at 149° C. In Fig. 5, the structure consists of large quantities of roughly triangular, occasionally filigreed, patches of $CuAl_2$, together with a moderate quantity of watery grey needles and filigreed areas of an iron-bearing constituent, the needles usually cutting through the $CuAl_2$. Smaller amount of purplish skeletons and particles of a second iron-bearing constituent is also present. Small blue particles of Mg_2Si also occur. The details of the structure are shown only at high magnification. On heat treatment, the $CuAl_2$ and iron-bearing skeletons were broken up, as is shown in Fig. 6. Fig. 7 shows the average microstructure of a hot-rolled duralumin slab (composition: 4.03% copper, 0.80 iron, 0.24 silicon, 0.45 magnesium, 0.59 manganese, 0.10 chromium and remainder aluminum). This was rolled at 450° C. from a 3-inch thick ingot to $^1/_4$ inch. Fig. 8 shows the average structure of 18-gage duralumin sheet after heat treatment consisting of heating for 30 minutes at 512° C., followed by oil quenching and air aging for six days. It will be seen that the amount of excess substance (mainly $CuAl_2$) is very much less in the heat-treated sheet than in the hot-rolled slab. Solution treatment caused the solution of a large part of the segregate substances.

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[2] R. S. Archer & Z. Jeffries, Aluminum Castings of High Strength. *Proceedings Institute of Metals Division, American Institute Mining & Metallurgical Engineers* (1927), pages 35–60.

[3] S. Daniels, Investigation of the Heat Treatment of Sand-Cast Duralumin. *U. S. Air Service Information Circular* No. 408, April 1, (1923), 13 pages.

The microstructures of commercial aluminum alloys, as cast, wrought or heat treated are generally complex and troublesome of interpretation. Dix and Keith[4] have listed the chief constituents found in these alloys and described their behavior with various etching reagents.

Alloys Used in Practice

Aluminum alloys suitable for the production of cast and wrought parts to be heat treated are rather numerous, but the bulk of present commercial requirements can readily be met with a relatively few compositions. The alloys used in practice may be divided roughly into two classes, viz., (1) those used for castings, and (2) those used for wrought products. Some alloys are employed both for casting and working, e. g., the alloy containing 4 to 5% copper (and with or without 0.25% magnesium) and so-called "Y" alloy. In practically all of the alloys used commercially the heat-treating effects are due either to $CuAl_2$ or Mg_2Si, or both. In some few alloys used in continental Europe, the hardening agent is Li_3Si or $MgZn_2$. In numerous instances, special compositions have been developed for particular purposes, e. g., cable alloys, compositions for forming, piston alloys, forging alloys, etc. If no other aluminum alloy were available, probably the best all-around composition would be the 92.5:4:1.5:2 aluminum-copper-magnesium-nickel alloy ("Y"). This is suitable for sand and permanent-mold casting, rolling and forging, and is heat treatable. The total of alloying constituents in the cable alloys is small, 1 to 2%. Most of the alloys for rolling and forging contain 4 to 6% of alloying elements. Casting alloys contain usually from 5 to 12% of added metals.

Alloys of the magnesium-silicide type are represented by such trade-named compositions as Aldrey, 51S, Aludur, Almalec, Montegal and the like. Aldrey, used extensively abroad for the production of cables for high-voltage electric-power transmission, contains about 0.4% magnesium, 0.6% silicon and remainder aluminum (plus normal impurities). The alloy called 51S, made by the Aluminum Company of America, contains 0.45 to 0.80% magnesium, 0.60 to 1.20% silicon and remainder aluminum. Alloys of this type are not used for castings but are employed chiefly for special purposes in the wrought condition. When fully heat treated, i. e., quenched and aged at moderately elevated temperature, wrought alloys of the magnesium-silicide type yield tensile strength of 45,000 to 50,000 lbs./in.^{2}, yield point of 30,000 to 40,000 lbs./in.^{2}, and elongation of 8 to 18%. Wrought alloys of the $CuAl_2$ type are represented commercially by Lautal and 25S. The former, made in Germany, has the nominal composition 94:4:2 aluminum-copper-silicon, while the latter, made by the Aluminum Company of America, contains 3.9 to 5.0% copper, 0.5 to 1.10 manganese, 0.5 to 1.10 silicon and the remainder aluminum. Worked and fully heat treated, these alloys yield tensile strength of 54,000 to 62,000 lbs./in.^{2}, yield point of 30,000 to 40,000 lbs./in.^{2}, and elongation of 16 to 24%.

Alloys of the combined $CuAl_2$ and Mg_2Si type are very numerous, most of them having been derived by some modification in the composition of duralumin. By duralumin is usually understood an alloy containing 3.5 to 4.5% copper, 0.4 to 1.0% manganese, 0.3 to 0.75% magnesium and remainder aluminum. Among commercial alloys of the duralumin class there may be mentioned 17S, Almag, Aldal, Alferium, Aeral, Avional and super-duralumin. Alloys of this type, depending upon the composition, when fully heat treated (this term here means that they have been so treated as to acquire maximum strength), yield tensile strength of 56,000 to 75,000 lbs./in.^{2}, yield point of 30,000 to 55,000 lbs./in.^{2} and elongation of 10 to 20%. So-called "Y" alloy, while used chiefly for castings, is rolled into sheet and bars and employed for forgings. When wrought and heat treated, its properties are approximately like those of the duralumin-type alloys. Most heat-treatable aluminum alloys to be used for working have been made the basis of patent claims.

Referring now to alloys for castings to be heat treated, the first alloy of note brought out was "Y" alloy. This finds application chiefly in England for high-duty service but is also used to some extent in the United States, particularly for aviation-engine castings. Aside from this alloy, there are two main classes of alloys used, viz., (1) the low-copper type, and (2) the high-copper type. The former is exemplified by alloys containing, say, 2.5 to 5% copper (with or without iron, magnesium or silicon) and remainder aluminum, and the latter by alloys containing about 10% copper (usually with magnesium) and remainder aluminum. The low-copper alloys are used for many kinds of castings postulating moderate to high strength, high to fair elongation, high to medium hardness and, or, good resistance to shock or alternating-fatigue stresses. The high-copper type is used chiefly where very high Brinell hardness is demanded—mainly in heat-treated pistons for motor-car engines. Fair strength, high hardness and poor elongation are the properties secured with this class of alloys. Among specific compositions used for castings, the following may be mentioned: 96:4 and 95:5 aluminum-copper; 95.75:4:0.25 and 94.8:5:0.2 aluminum-copper-magnesium; 94:4:2, 94:5:1, and 93:2:5 aluminum-copper-silicon; 88.5:10:1.25:0.25 aluminum-copper-iron-magnesium; and 88.75:10:0.25:1 aluminum-copper-magnesium-silicon. The chief requirements of the U. S. Army Air Service for heat-treated cast parts are met with four alloys. These include the 88.5:10:1.25:0.25 aluminum-copper-iron-magnesium alloy (for pistons and bearings), the 92.5:4:1.5:2 aluminum-copper magnesium-nickel alloy (for pistons, air-cooled cylinder heads, and bearings), the low-copper type having the nominal composition 95.75:2.5:1.25:0.5 aluminum-copper-iron-magnesium (for housings and brackets), and the 94:5:1 aluminum-copper-silicon alloy (for crankcases, water jackets, levers and wheel spiders).

Current tentatively revised specifications of the Society of Automotive Engineers for general heat-treated castings (S. A. E. No. 38) give the following limits of chemical composition:

Copper	4.0 to 5.0 %
Silicon (maximum)	1.20%
Iron (maximum)	1.20%
Zinc (maximum)	0.25%
Total of all constituents except aluminum and copper is to be not over	2.5 %

When high resistance to shock and maximum toughness are required, heat treatment for this alloy consists in soaking, quenching and air aging. So treated, the tensile strength is about 33,000 lbs./in.^{2} and the elongation about 9% for sand-cast bars. The strength increases somewhat more and the elongation decreases on air aging for several months, while the yield point rises to well over 20,000 lbs./in.^{2} If greater strength, yield point and hardness are required, the alloy is aged (after quenching) at moderately elevated temperature to give about 36,000 lbs./in.^{2} tensile strength and 5% elongation. The aging treatment may further be varied to provide tensile strength of around 45,000 lbs./in.^{2} and elongation of about 2%.

Effect of Heat Treatment on Mechanical Properties

Pure aluminum has tensile strength of about 8500 lbs./in.^{2}, elongation of 60%, and Brinell hardness of about 16. Commercial 99+% metal (containing say 99.4% aluminum with impurities normal) has tensile strength of about 13,000 lbs./in.^{2}, elongation of 45% and Brinell hardness of 23. These figures refer to metal in the wrought and annealed condition. By suitable alloying and heat treatment, castings are produced with tensile strength of 48,000 lbs./in.^{2}, elongation of 1% and Brinell hardness of 160, or tensile strength of 38,000 lbs./in.^{2}, elongation of 7% and Brinell hardness of 85. Wrought and heat-treated duralumin has tensile strength of, say, 63,000 lbs./in.^{2}, elongation of 20% and Brinell hardness of 105. Quenched and air-aged wrought magnesium-silicide alloys have tensile strength of around 35,000 lbs./in.^{2}, elongation of 28% and Brinell hardness of 65. Prior to the development of heat treatment the usual aluminum casting alloy employed in practice had tensile strength of 19,000 lbs./in.^{2}, elongation of 1.5% and Brinell hardness of 65. With certain cast alloys, it is possible to more than double the tensile strength and elongation, increase the hardness by 75% and about triple the yield point by suitable heat treatment. In other alloys, a given heat treatment will have little effect on the hardness or strength, but will nearly triple the elongation. In still other alloys, the strength may be increased about 50%, the elongation but little affected and the hardness raised about 50%. Heat treatment of annealed wrought alloys may about double the strength and hardness, affect the elongation but slightly or reduce it 50% and increase the yield point about seven fold.

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[4] E. H Dix, Jr., & W. D. Keith, The Etching Characteristics of Constituents in Commercial Aluminum Alloys. *Proceedings American Society for Testing Materials*, Vol. 26, Part II (1926), pages 317-334.

The data available regarding the effects of different heat treatments on sundry mechanical properties of aluminum alloys, both cast and wrought, are now very numerous. Detailed information may be had from the large literature on the subject, and in the present paper only a few figures will be given to reflect the general trend of results being obtained. In the case of commercial castings, the mechanical properties obtained are not necessarily so good as those given by test bars, in part because of the mass effect and in part because laboratory methods of handling and control cannot be economically put into production practice. Tests of sheet products are usually made by cutting bars from the actual sheet, which can be readily done without spoiling the product as would be the case with castings, and hence give the actual properties.

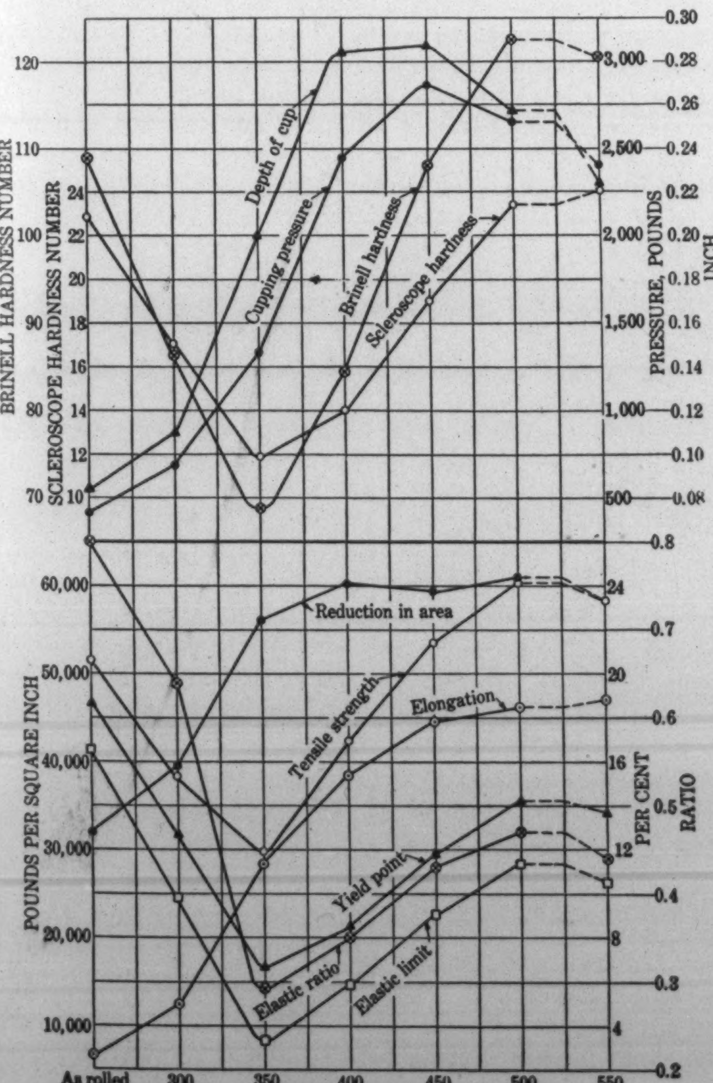

Fig. 9—Some Mechanical Properties of 18-Gage Duralumin Sheet, as Affected by Heating and Air Cooling

Table 1

Mechanical Properties of Some Wrought Aluminum Alloys, as Affected by Heat Treatment[a]

Symbol	Heat Treatment	Yield Point Lbs./In.^{2}	Tensile Strength Lbs./In.^{2}	Elongation in 2 Inches %	Brinell Hardness (500 kg. 10 mm.)
17ST	Quenched and aged at room temperature	30,000–40,000	55,000–63,000	18–25	90–105
17SO	Annealed	7,000–10,000	25,000–35,000	14–22	45–55
25SO	Annealed	7,000–12,000	23,000–35,000	12–20	45–55
25SW	Quenched and aged at room temperature	15,000–30,000	45,000–53,000	15–22	68–85
25ST	Quenched and aged at elevated temperatures	30,000–40,000	55,000–63,000	16–25	90–105
51SO	Annealed	4,000– 6,000	14,000–19,000	22–32	25–32
51SW	Quenched and aged at room temperature	15,000–20,000	30,000–40,000	20–30	55–70
51ST	Quenched and aged at elevated temperatures	30,000–40,000	45,000–50,000	10–18	90–100

[a] Heat Treatment of Wrought Aluminum Alloys of High Strength. *American Society Steel Treating Handbook*, Sheet Al-5601, Sept. 1927.

Table 1 gives the tensile properties and hardness of the wrought alloys 17S, 25S and 51S, as made by the Aluminum Company of America. The properties are typical of wrought alloys of the $CuAl_2 + Mg_2Si$ (duralumin), $CuAl_2$ and Mg_2Si types, respectively. The specific gravity of 17S and 25S is about 2.79 and of 51S is 2.69. The effects of various heat treatments on the tensile properties, hardness and cupping values of duralumin sheet have been studied by the writer.[5] Fig. 9 is a graph showing the effects of heating cold-rolled 18-gage sheet for 30 minutes in the range of temperature 300° to 550° C., followed by air cooling (and then air aging for six days at room temperature). It is seen that the annealing temperature is 350° C. and that the alloy is air quenching. Fig. 10 is a graph showing the effects of water quenching the same material after heating for 30 minutes in the range of temperature 375° C. to 550° C., followed

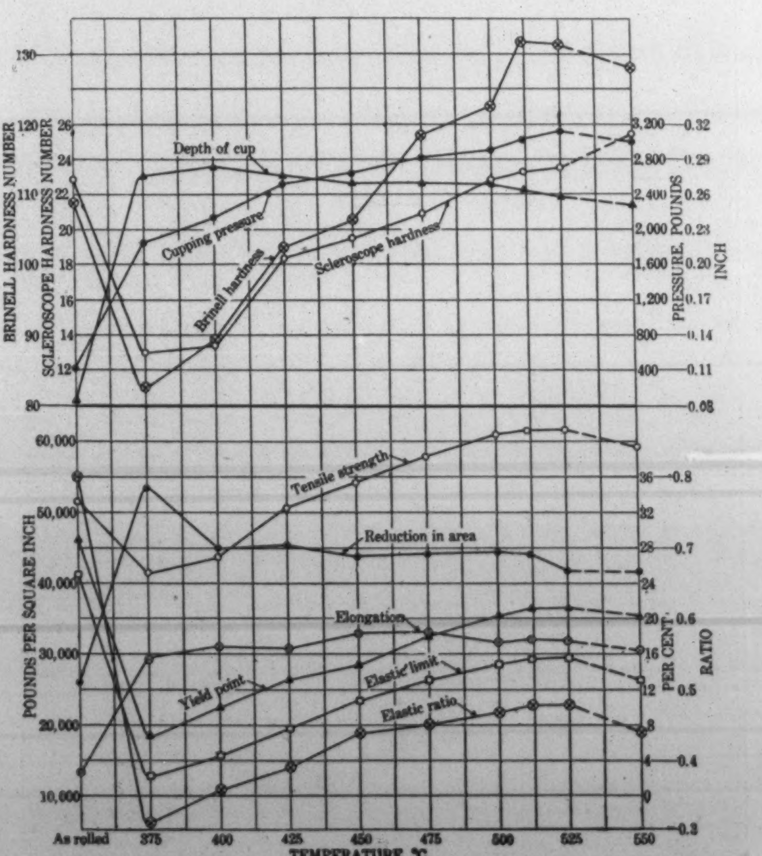

Fig. 10—Some Mechanical Properties of Duralumin Sheet, as Affected by Water Quenching and Air Aging

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[5] R. J. Anderson, Some Mechanical Properties of Duralumin Sheet as Affected by Heat Treatment. *Proceedings American Society Testing Materials*, Vol. 26, Part II (1926), pages 349–375.

by aging for six days at room temperature. It is seen that the preferred quenching temperature is around 512° C.

Table 2 gives some data showing the effect of a heat treatment on various properties of a sand-cast alloy containing about 4.9% copper, 0.8% silicon, 0.6% iron and remainder aluminum. The heat treatment entailed soaking for 24 hours at 510° C., followed by quenching in boiling water, and then aging in boiling water for two hours at about 125° C. The marked enhancement of properties may be noted. Table 3 shows some data on the effects of different heat treatments on some properties of sand-cast "Y" alloy. Table 4 gives some figures for the tensile properties and hardness of various alloys as cast and heat treated. Roughly, by heat treatment the impact resistance and safe range of fatigue stress are more than doubled for cast alloys.

Heat treatment has a marked effect on machinability, and this must be taken into account when tooling for heat-treated manufactures. Heat treatment improves the corrosion resistance of certain alloys. Work by Rawdon[6] has shown that duralumin sheet quenched in hot water has a much greater tendency toward intercrystalline attack than when quenched in cold water.

Table 2
Some Mechanical Properties of 94:5:1 Aluminum-Copper-Silicon Alloy, as Sand Cast and Heat Treated[a]

Property	As Cast	Heat Treated[b]
Tensile strength, lbs./in.^{2}	21,500	31,000
Proportional limit (tension), lbs./in.^{2}	4,900	8,600
Elongation, in 2-inches, %	2.2	5.5
Compressive strength, lbs./in.^{2}	35,100	43,700
Charpy impact resistance, ft.-lbs.	1.4	3.2
Brinell hardness (500 kg., 10 mm.)	60	75

[a] Tests by Daniels and Warner.
[b] For heat treatment, see text

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[6] H. S. Rawdon, Corrosion Embrittlement of Duralumin. III. Effect of the Previous Treatment of Sheet Material on the Susceptibility to This Type of Corrosion. *Technical Notes* No. 284, National Advisory Committee for Aeronautics, April, 1928, 24 pages.

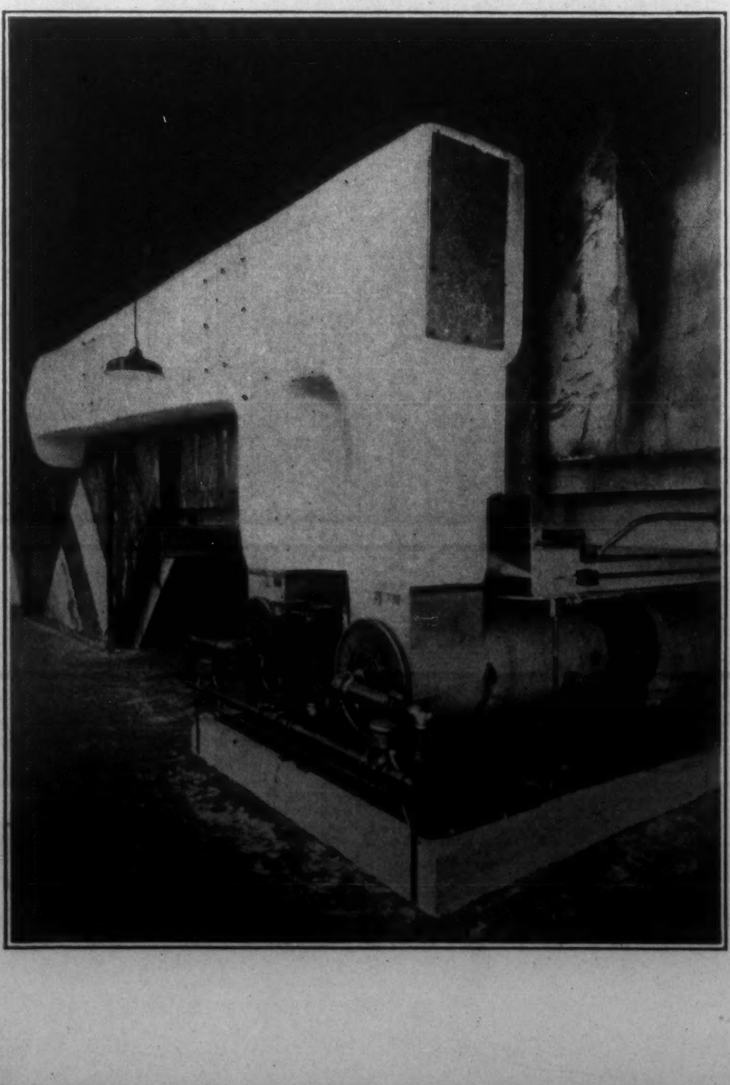
(*To be concluded in October*)

Recirculation and Incineration Japanning and Baking Oven

By A. E. Maehler*

While certain noteworthy improvements in oven construction have been perfected in the past decade, the matter of providing safe, clean, efficient heat for industrial ovens has come in for careful constructive consideration only during the past three years. Most ovens installed up until a few years ago were heated by radiant type heaters installed within the oven and heated by gas, electricity or fuel oil. It will be readily understood that, in a heater of this type, it is necessary to bring the radiators to a very high temperature before effective radiation begins. This calls for an excessive fuel consumption in heating up the oven. Another disadvantage of the radiant type heater is the failure of even the most efficient types to provide anything approaching an even temperature in all parts of the oven. The temperature at the floor is often as much as 100° lower than that at the ceiling or in front of the radiators. A serious hazard is created in ovens of this type by the presence of explosive vapors distilled from the japan or enamel and numerous explosions and often disastrous fires have resulted from the presence of these volatile gases under the high compression created by the expansion of the oven air under heating.

While attempts have been made to overcome the dangers of explosion by the use of ventilating fans to draw off the hazardous vapors, this measure often results in the introduction of a sufficient quantity of fresh air to create a highly combustible mixture and serves to increase the danger. Great heat losses also result since fresh air induced into the oven to replace that drawn off by the ventilating fans must be heated to full oven temperature.



Recirculation and incineration are the results of careful scientific study to overcome the dangers and increase the efficiency of industrial baking. Recirculation means simply withdrawing, reheating and return of the air, known in such installations as the circulating medium.

To achieve the desired results, an entirely new type of industrial oven heater, known as the Maehler-Universal Heater, has been developed.

The use of low pressure heated air places the heater outside the oven where it is accessible at all times during operation and permits the use of much more efficient heating equipment.

The circulating medium is drawn from the top of the oven by a high temperature suction fan located at the exhaust end of the heater, passes through the heater and returns through the fan to the bottom of the oven. The fan being of the suction type drawing the air through the heater, and an independent throat and air intake for gas combustion being provided, a soft, quiet visible burner flame is produced and the use of a visible pilot and automatic electric ignition is possible. An adjustable fresh air inlet at the intake end of the heater permits the introduction of fresh air into the heater at room temperature, when desired.

In the operation of the heater, the air from the oven with its vapor content passes through the heater flame where all explosive gases developed in the oven are incinerated, the burning of the vapors generating approximately 150,000 B. t. u. per gallon of enamel distilled from work in process. As the entire volume of circulating medium passes through the heater many times a minute, it will be seen that it is never possible for it to contain sufficient volatile vapors to create even the slightest possibility of explosion.

The heater, which under repeated tests has shown a continuous efficiency of 95–99%, operates at 33$^{1}/_{3}$% above oven temperature. At 450° F. oven temperature, for instance, the circulating air is normally returned to the heater at 400° F. and it is, therefore, necessary to raise its temperature but 50% to maintain the oven temperature. The fuel economy is readily apparent. A highly accurate thermostatic control which can be set for any desired temperature controls the fuel flow to maintain the oven temperature at the setting.

Notwithstanding the constant recirculation of the air, repeated tests have shown the loss in the oxygen content of the circulating medium never exceeds 2%, even after many hours of operation. The oxidizing effect of the air is, therefore, in no way reduced, nor can it possibly fall to a point where there is danger of explosion.

Full circulation of the air to all parts of the oven is provided by the slight plus pressure generated and the variation in temperature at any two points in the oven is rarely over 6° and never over 10°. The floor, usually the coldest part of the oven, becomes the warmest.

* Secretary, The Paul Maehler Company.

Automatic Preparation of Metallographic Samples

By R. G. Guthrie & J. A. Comstock

The polishing of a specimen for metallographic examination, as usually performed, is an art rather than a science. Not every metallographer is an expert at the art and many specimens are so faultily prepared that no sound conclusions can be drawn from the micrographs. Hence, there is good reason for the elimination of the human element. This paper, and that by Epstein in our November, 1929, issue, record steps in the right direction. And not only are the results of automatic polishing better, but when many specimens have to be prepared, they are also cheaper.

The trend of development in sample preparation for metallographic microscopes is increasingly toward the optically plain or flat surface before etching, with a minimum of relief of the harder constituents and the least possible polishing film.

This condition is the direct result of and contemporary with refinements in microscopy which from time to time have appeared to increase the useful resolution and enlargement of the metallographic microscope, and which require for maximum results obtainable from the best objectives the flattest and most shallow surface structure that can be arrived at. This is an absolute necessity for the obvious reason that the higher the power of the objective the less is its depth of focus, and to produce a clean cut photomicrograph the depth of relief of the polished and etched surface must not be in excess of the working depth of focus of the objective used.

At first thought this condition might seem to indicate that the higher the power of the photomicrograph the "flatter" it must of necessity be, but fortunately the development of so-called conical illumination has made it possible to study and photograph at high powers the shallowest of polished and etched structures with even greater effective relief than was previously possible only at low powers using lenses with a relatively great depth of focus. An extensive use of this method of illumination has borne out the fact that maximum results here are even more dependent upon the shallowness of the polished and etched structure than with plain axial or flat illumination.

These refinements in photomicrography have naturally enough led to parallel refinements in methods and apparatus for sample preparation. Methods which formerly gave satis factory results with the best obtainable microscopic equipment can no longer be used where current microscopic equipment is in use. For example, it has been found that heavy cloth wheels such as canvas not only pile up excessive and uneven cold-worked films but they also wipe out the brittle non-metallic inclusions as well as the softer metal constituents leaving the hard constituents in relief polish. This fact has promoted the use of wheels which have no surface weave or fiber or nap that can produce a whipping or wiping action on the sample. One such wheel that has given extremely satisfactory service is the paraffin coated disc lubricated with a soap solution. Another example is in the case of the grinding and polishing machines formerly considered quite satisfactory but which, due to the human factor, were unable to duplicate samples having a surface polished optically flat to the edge due to rocking of the sample in hands of the operator, while irregular and at times excessive pressure, even in the hands of experienced operators, caused considerable loss of time in polishing due to scratching and consequently a thick film would be built up which never etches off evenly. To get away from these troubles it was necessary to devise a grinding and polishing machine which would eliminate the human equation, and the result was such a machine as shown in Fig. 21 which makes use of automatic magnetic sample holders. By this means it is possible to control all the factors entering into the polishing operation, which will be expanded on further in this paper, and at the

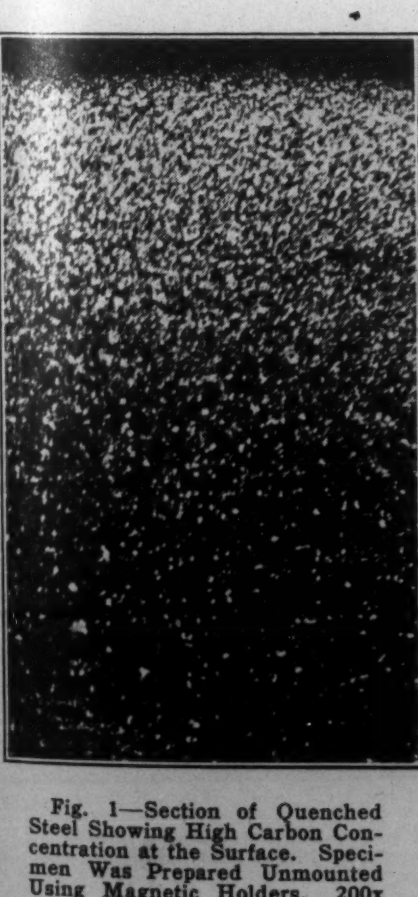


Fig. 1—Section of Quenched Steel Showing High Carbon Concentration at the Surface. Specimen Was Prepared Unmounted Using Magnetic Holders. 200x

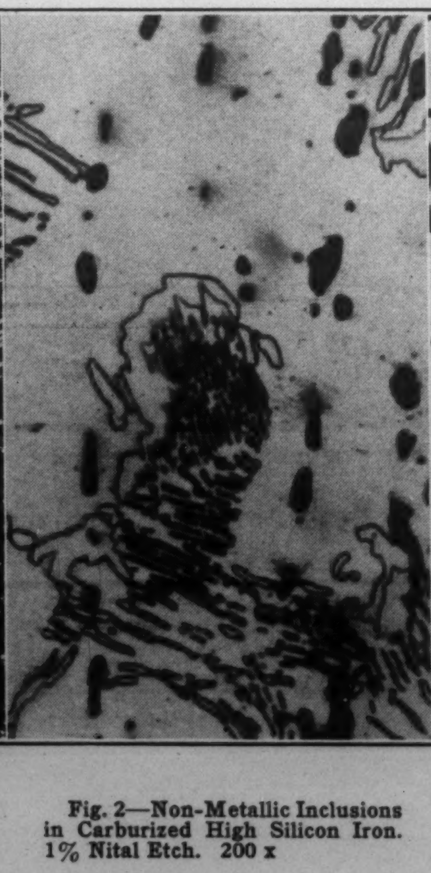


Fig. 2—Non-Metallic Inclusions in Carburized High Silicon Iron. 1% Nital Etch. 200 x

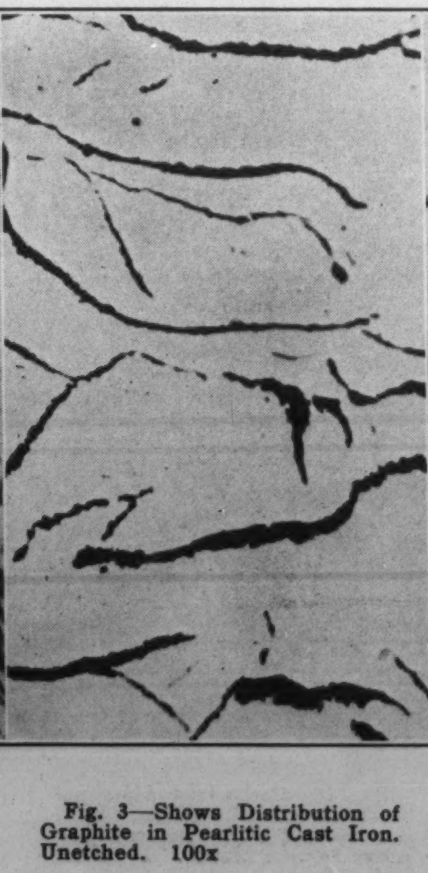


Fig. 3—Shows Distribution of Graphite in Pearlitic Cast Iron. Unetched. 100x

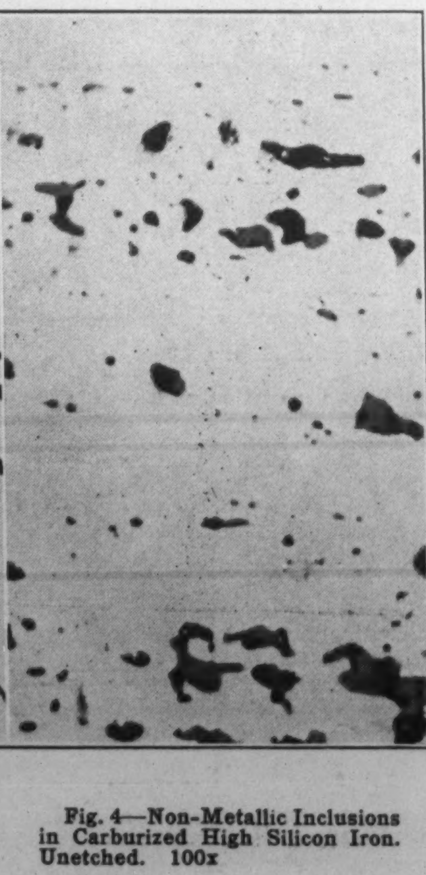


Fig. 4—Non-Metallic Inclusions in Carburized High Silicon Iron. Unetched. 100x

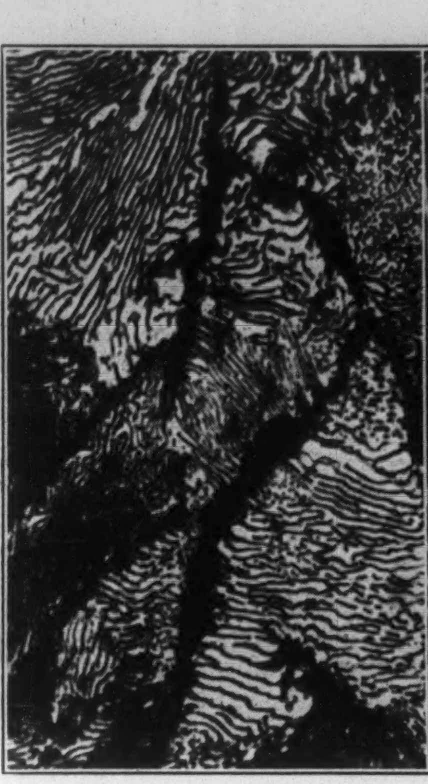


Fig. 5—Pearlitic Cast Iron. 1% Nital Etch. 400x

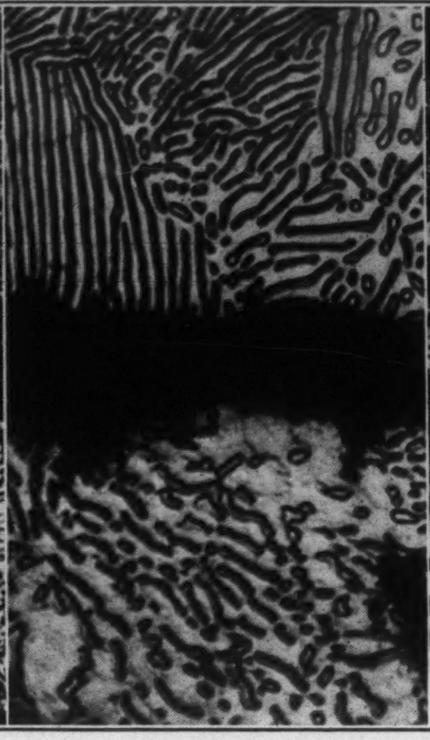


Fig. 6—Pearlitic Cast Iron. 1% Nital Etch. 1300x

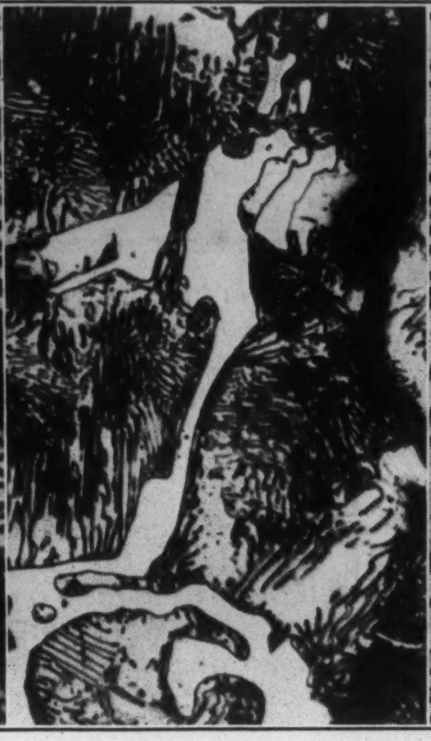


Fig. 7—Mottled Iron. 1% Nital Etch. 400x

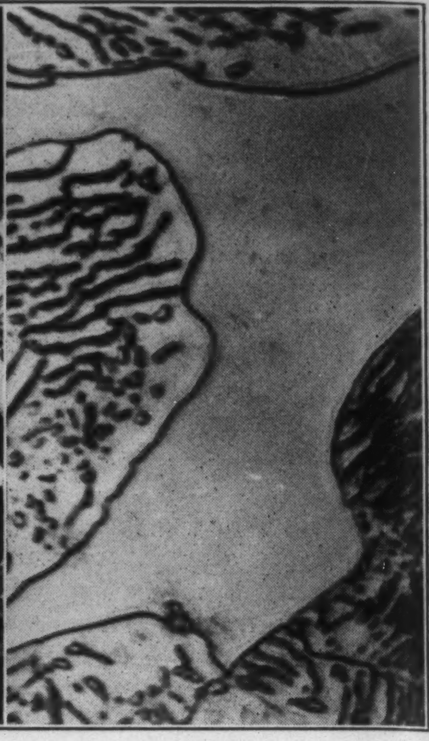


Fig. 8—Mottled Iron. 1% Nital Etch. 1300x

same time do away with the evil of rocking and the development of new facets whenever the sample is replaced on the wheel. These advantages are, of course, exclusive of the great saving in the operator's time, due to automatic operation and ease of duplication of results.

Fundamental Considerations

Sample preparation consists of removing metal to obtain an optically plane surface and then by cold work to cause a flow of the surface metal to produce a polished condition. These two actions, removing material and cold working, occur in varying and opposite degrees in both the actual processes of grinding and polishing. An examination under the microscope of a cut made by an abrasive particle shows where the metal has been removed and the surface of the trough is highly polished by the cold work received from the cutting abrasive. In this case the removal of material is desired and actually predominates. On the other hand, where polishing is desired, the cold work is at a maximum due to the friction between the sample and the polishing wheel and the removal of material is small but actual, as evidenced by the dirty looking wheel after use.

The necessary contact in grinding between the sample and the grinding wheel is on the coarse abrasive particles themselves, the wheel matrix or bond not entering into the action under ideal conditions. On the other hand, in polishing, the contact is between the polishing wheel itself and the surface of the sample, the polishing powder being added to increase the frictional resistance due to its hardness and extreme fineness.

Since it is highly desirable to control the actions of material removal and cold work in the processes of grinding and polishing, making the cold work a minimum in grinding and the material removal a minimum in polishing, it is important to understand the factors which influence them.

In the case of grinding if the bond is too hard the wheel will very readily glaze over in use and lose its free cutting properties and in this condition the surface of the specimen receives considerable cold work which, if carried to any appreciable extent, causes a smearing over of the abrasions

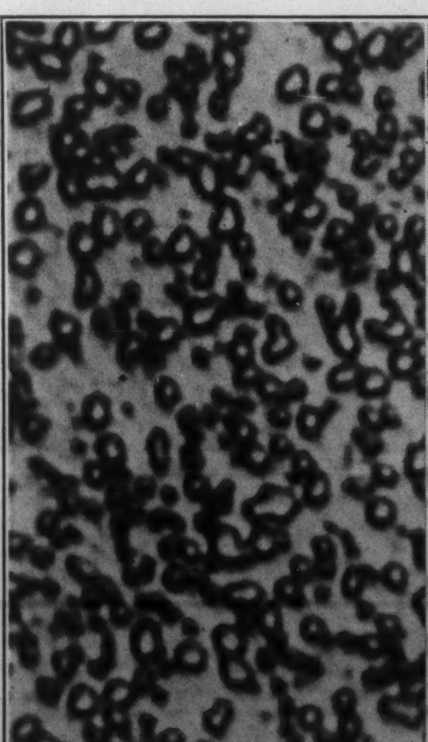


Fig. 9—Spheroidized Cementite. 2% Nital Etch. 1300x

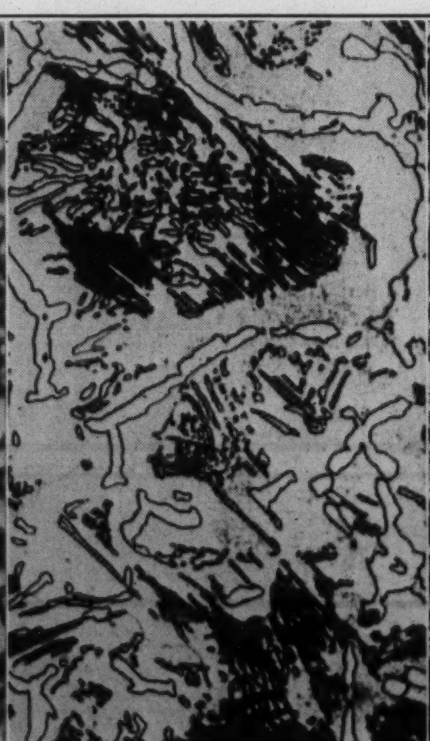


Fig. 10—Carburized Abnormal Steel, Annealed Condition. Dark Pearlite and White Cementite in White Ferritic Matrix. 1% Nital Etch. 400x

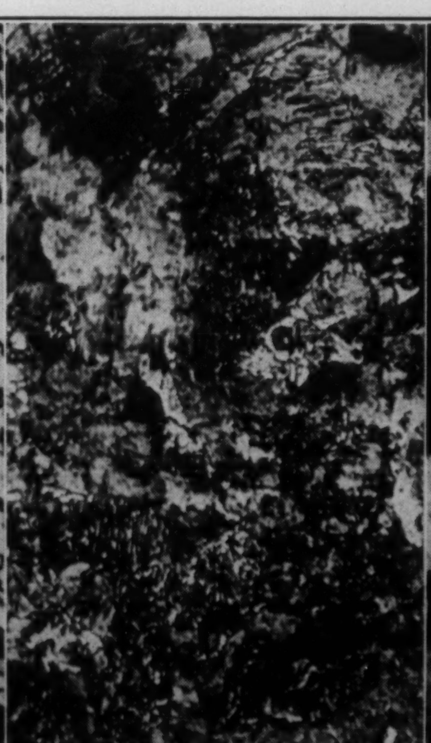


Fig. 11—Sorbite. 1% Nital Etch. 400x

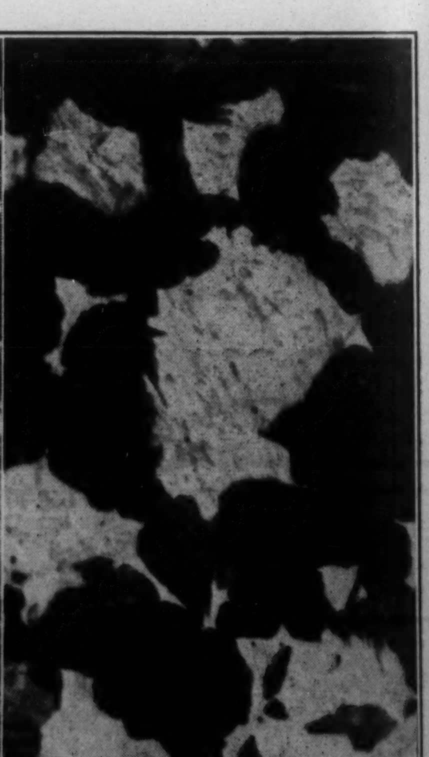


Fig. 12—Martensite and troostite. 5% Picral Etch. 400x

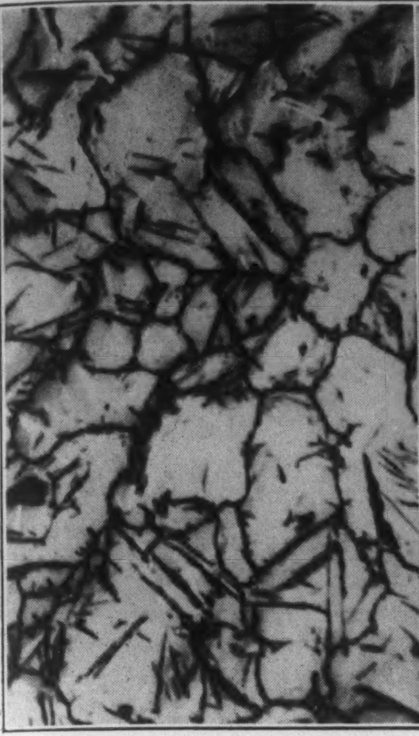


Fig. 13—Hadfield's Manganese Steel as Forged. Hardness 241. Combination Nital and Picral Etch. 400x

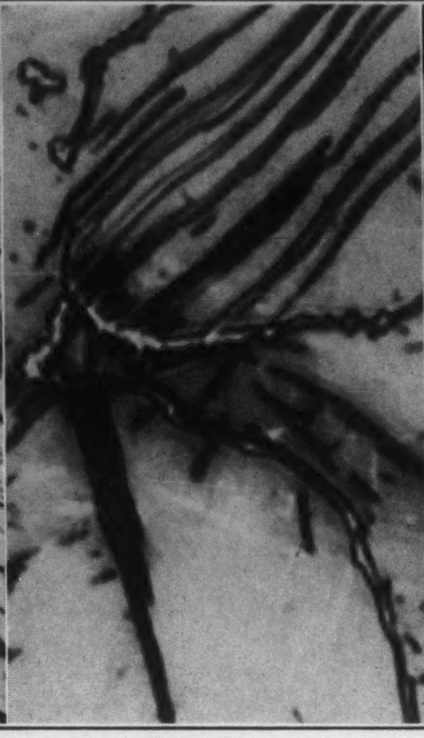


Fig. 14—Hadfield's Manganese Steel as Forged. Hardness 241. Combination Nital and Picral Etch. 2000x

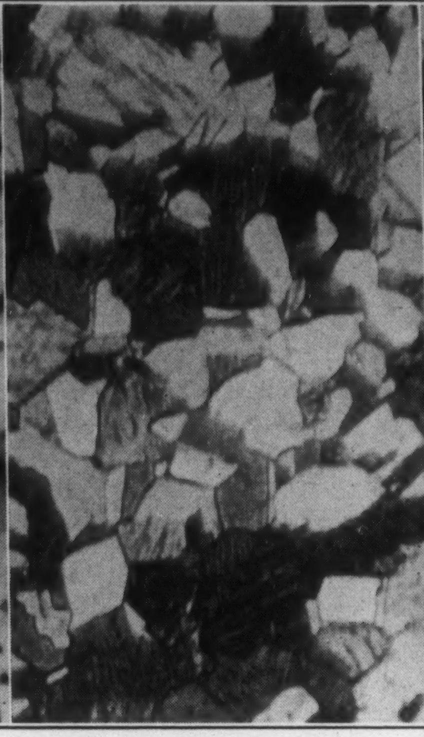


Fig. 15—Hadfield's Manganese Steel Quenched from 1000° C. in Water. Hardness 228. Combination Nital and Picral Etch. 125x

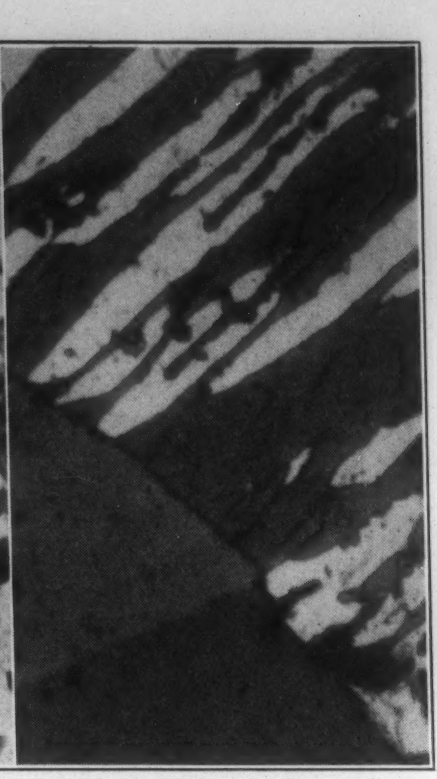


Fig. 16—Hadfield's Manganese Steel Quenched from 1000° C. in Water. Hardness 228. Combination Nital and Picral Etch. 400x

instead of removing them, and later starts spalling out the surface. On the other hand if the bond is too soft the abrasive particles will be too easily loosened from the wheel and will not receive sufficient propelling force to make a clean cut but will tend to roll around under the specimen and scour the surface. A visual inspection of the ground surface of the sample usually tells the story of the condition of the wheel; if it is dull in appearance the wheel is too soft for the speed and pressure; if it is clean cut and bright the bond is right for the speed and pressure; if it is smeared and bright the bond is too hard and the wheel has glazed.

In the case of polishing the evidence on the sample of material removal is, of course, the scratches. Where the polishing powder is harder than the specimen, as in the case of levigated alumina and ferrite, the specimen will be scratched if the alumina is too coarse or the pressure too great in which case the scratches are too deep to be covered over by the flow of metal due to the cold working action. As a polishing powder which approaches the hardness of the ferrite is used the scratches or abrasions will become more shallow and fewer for the same pressure. There is a definite balance between the (1) hardness of the abrasive, (2) the size of its coarsest particles, (3) the pressure on the sample, and (4) the amount of cold work which draws the line between a scratchless polished surface and one which shows scratches.

The cold work produced on the surface of the sample is proportional to the frictional resistance between the wheel and the sample, and may be stated mathematically by the equation:

$$H \,\&\, CW = k(f \times P),$$

where H = heat generated by friction.
CW = Cold work produced by friction.
f = kinetic coefficient of friction.
P = normal pressure on sample.

The kinetic coefficient of friction is dependent upon the nature of the surfaces in contact. This factor is controlled by the hardness and fineness of the polishing powder, the nature of the cloth and the dampness of the wheel. In practical operation the size of the coarsest particles of the polishing powder limits the amount of pressure which can be applied to the sample without producing scratches.

Operation of Polishing Machine

The automatic polishing machine carries four vertical spindles with removable horizontally rotating discs which are used in order from left to right in carrying out the grinding operations on the first two and the polishing operations on the second two. These latter are equipped with automatic magnetic sample holders. These holders consist of a solenoid mounted beneath the revolving non-magnetic brass disc, and an adjustable holder arm which will accommodate any ordinary size and shape sample, the solenoid and holder arm being connected together and oscillated so that the sample travels back and forth from the periphery to the center of the disc to simulate hand motion. This is done by an arrangement of gears belt-driven from the vertical spindle carrying the disc. The pole piece of the solenoid is aligned directly beneath the position of the sample in the holder arm above the disc so that the pull on the sample, and hence the pressure on the sample, is always normal to the surface. A constant current passing through the solenoid provides a constant, unvarying pressure on the sample. These two final wheels are also supplied with an automatic solution agitator and dripping device consisting of a small blower operated off the main drive arrangement for bubbling the air from the blower through the solutions, thereby keeping them uniform and active, and proper connections to high covers over the wheels, making it possible to operate with the covers down to prevent contamination of the wheels when the coarse and medium grinding wheels are operating at the same time. (See Table I for more detailed description of this operation.)

Advantages of Automatic Preparation

The principal advantages of automatic sample preparation are obvious but may be summarized in the order of their importance as follows:

(a) Improved quality of the prepared surfaces.
(b) Decreased cost of sample preparation.

It has been our desire to improve the quality of the sample preparation and at the same time simplify the operations. To do this it was necessary to remove, in so far as possible, the human equation both to save the time of the operator and remove the variables incident thereto; hence, the magnetic oscillating specimen holders, deep covers, with the agitating and dropping devices. The common faults of rolling or rocking the sample, thereby producing curved edges, as well as uneven films of cold worked material on the surfaces, have been minimized by the design of the machine which is thoroughly precision throughout. The jump-

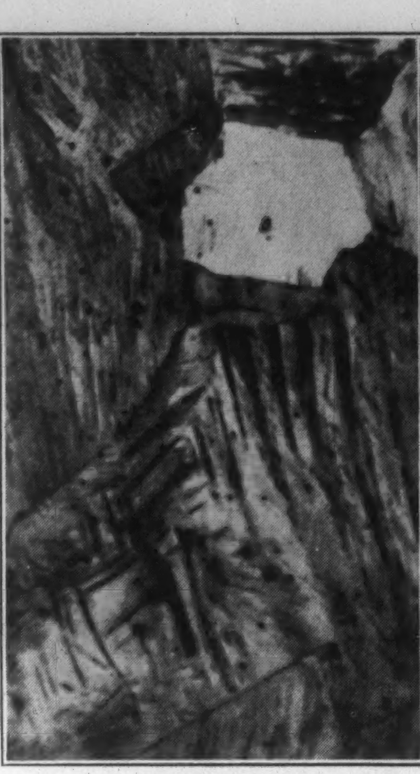


Fig. 17—Hadfield's Manganese Steel Quenched and Strained in Tension. Hardness 544. Combination Nital and Picral Etch. 400x

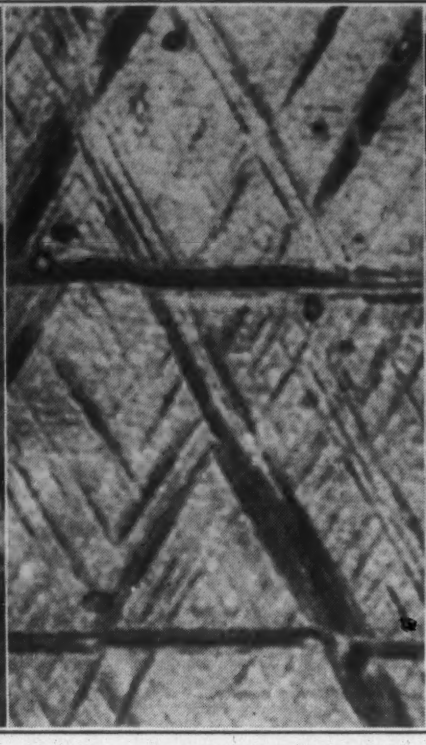


Fig. 18—Hadfield's Manganese Steel Quenched and Strained in Tension. Hardness 544. Combination Nital and Picral Etch. 2000x

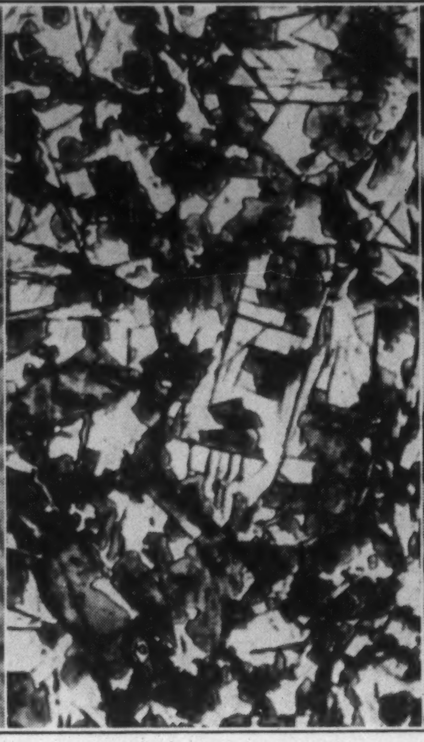


Fig. 19—Hadfield's Manganese Steel Annealed at 500° C. for 60 Hours. Hardness 454. Combination Nital and Picral Etch. 400x

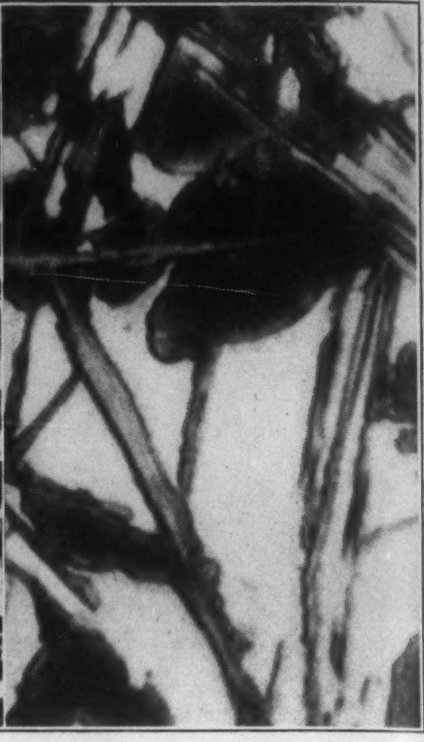


Fig. 20—Hadfield's Manganese Steel Annealed at 500° C. for 60 Hours. Hardness 454. Combination Nital and Picral Etch. 2000x

Table I Automatic Sample Preparation

GRINDING		
1.	*Rough Grinding:*	Rough specimen flat on a dry alundum vitreous bond wheel—80 mesh, bond M—operating 1500 to 3600 r. p. m.
2	*Medium Grinding:*	Remove previous abrasions on a dry alundum vitreous bond wheel—150 mesh, bond M—operating 1500 to 3600 r. p. m.
3.	*Fine Grinding:*	Remove previous abrasions on a paraffin-covered disc, carrying carborundum grain—No. 180 to No. 320—in a liquid soap vehicle operating 1500 r. p. m. Prepare disc by covering $^{3}/_{16}''$ deep with molten Standard Oil Company parawax and allow to solidify. By means of a simple tool, remove a V-cut of parawax about $^{1}/_{16}''$ deep from center to the periphery. Radial grooves to be spaced about $^{1}/_{4}''$ apart at the periphery. Grinding solution made approximately 50–50 liquid soap and water with added carborundum grain, and mixture applied with brush to surface of paraffin.
POLISHING		
1.	*Coarse Polishing:*	Remove previous abrasions on flannel-covered disc, carrying No. 1 levigated alumnia in distilled water, operating 1500 r. p. m.
2.	*Medium Polishing:*	Remove previous abrasions on flannel-covered disc, carrying No. 3 levigated alumina in distilled water, operating 1500 r. p. m.
3.	*Fine Polishing:*	Remove previous abrasions on kitten's ear velvet covered disc, carrying Merck's Reagent magnesia free from sulphates in denatured alcohol, operating 1500 r. p. m. Wash under hot water faucet and dry in air (by blowing).

ing or vibration of the grinding and polishing wheels has been eliminated also by machine design and precision fitting.

A further factor affecting the quality of the prepared surfaces is the technique of the mode of procedure which has been simplified many times. The reasons for and results of these methods have been fully explained in the foregoing text. The evolution of this method, as well as the evolution of the machine is clearly seen by a perusal of the previous papers prepared by the authors.[1]

In the matter of decreased cost of sample preparation, no particular effort was made but happily this followed as a natural consequence. In attempting to procure the best possible surface for microexamination, we simplified all operations to their minimum primarily to reduce the variables and secondarily to reduce the time incident to their preparation, with the result that in using this machine the average production rate for the samples from which the photomicrographs in this paper were made was about seven minutes each, or eight samples per hour.

The photomicrographs contained herein are for the most part self explanatory by their sub titles and the metallographist will readily understand why those subjects were chosen. It has been our aim to select a general class of subjects that represent truly hard surfaces in which all the constituents are of about the same order of hardness; samples representing several constituents of varying degrees and orders of hardness; and samples containing constituents and inclusions that are normally difficult to prepare and still retain the true proximity of the very soft or readily erasible inclusions.

In all these photomicrographs, especially at the higher powers, the microscope was firmly locked or "frozen" in focus by the use of a magnetic brake on the fine adjustment, which device prevents the machine or its component parts from settling or moving out of focus during exposure. It was possible to expose any number of plates at even the highest powers and produce the same focus on all of them without refocusing.

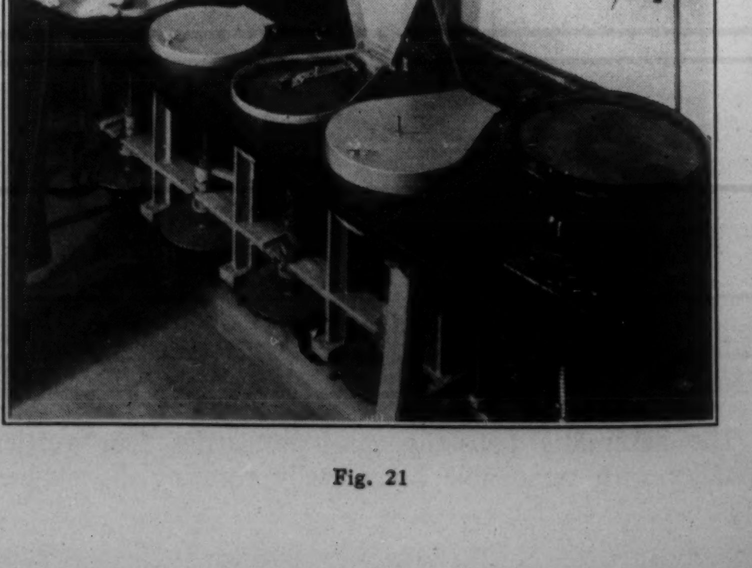


Fig. 21

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[1] "High Power Magnification in Metallography," *Transactions American Society for Steel Treating*, Jan. 1925, pages 4–22.
"Sample Preparation for High Power Photomicrography," *Transactions American Society for Steel Treating*, Mar. 1925, pages 337–362.

Critical Abstract

Dr. Gillett, the editorial staff and specially selected contributors will prepare abstracts of a critical nature on articles of special importance. The current literature will be covered in the Abstracts of Current Metallurgical Literature.

A Study of Slip Lines, Strain Lines and Cracks in Metals under Repeated Stress*

By turning down two portions of a rotating-beam endurance bar, and running the bar at a load at which fracture ensues in one of the reduced sections, the unbroken reduced section, which has been subjected to the same load as the broken one, is damaged by the repeated stress. This "fatigue-damaged" section may be compared with the adjacent unreduced section, which is subject to a load that is below the endurance limit, and which, therefore, does not damage the metal, or may even strengthen it by under-stressing.

The damaged and undamaged sections were compared by making tensile or torsion tests, and noting any difference in behavior of the two sections.

Comparisons were made on Armco iron, box annealed, 40,000 tensile; 0.20% C carbon steel (S. A. E. 1020) as rolled, 58,000 tensile; 0.35% C, 1.25% Ni, 0.60% Cr steel (S. A. E. 3135) as rolled, 102,000 tensile; stainless iron, 0.09% C, 13% Cr, as rolled, 87,000 tensile; 60:40 brass, heated to 1000° F., 30 min., air cooled, 49,000 tensile; monel metal, as rolled, 79,000 tensile; and duralumin, rolled and heat-treated to 53,600 tensile, 18.5% elongation.

Some specimens were run at loads below the endurance limit. The bulletin is not quite clear as to whether the comparisons tabulated between damaged and undamaged metal exclude those bars whose reduced portions were not overstressed, and the degree of overstress was seldom the same in any two bars, as a series of bars with reduced sections were run at varying loads as in an ordinary fatigue test.

It is, therefore, somewhat difficult to draw quantitative conclusions from the averaged results that are tabulated, since it is not clearly stated just which bars were averaged, though the loads and number of cycles for each bar are given. Even without complete details, the qualitative results are interesting, showing decided differences in behavior among the various alloys.

Instead of a smoothly radiused test section as is used in most fatigue testing, these bars had a $^1/_3$" radius between the $^1/_3$" and the $^1/_2$" diameter sections of the bar. The Cr Ni steel specimens broke at the beginning of the fillet, illustrating the greater sensitiveness of the harder alloy to stress concentration.

Hardness tests on the $^1/_3$" and $^1/_2$" sections, the former being damaged, the latter not, showed the former to have increased from 18–30 Rockwell B in Armco iron, from 55–60 in the 0.20% C steel and from $13^1/_2$–16 in the brass. The other materials showed no significant change. Hardening of the softer materials, without perceptible change in dimensions, was thus evident.

By making a tensile test on a bar, half damaged and half undamaged, and noting the diameter of each portion of the bar, when the bar as a whole had been stretched, it was found that the reduction of area of the damaged portion was distinctly less than that of the undamaged portion in Armco and 0.20% C steel. This ties in with the change of hardness, or it may be due to the presence of incipient fatigue cracks which might act the same as grooves or nicks would. On the other hand, the stainless iron showed a greater reduction in the damaged portion, while the changes in the other materials were not significant. Yield started first in the undamaged section in all but the 0.20% C steel and the Cr Ni steel.

In the study of slip lines, it was shown that in Armco and 0.20% C steel, many slip lines developed before a crack became visible, while in brass, duralumin and monel, cracks appeared before any slip lines could be found.

Whether the crack starts before or after slip, its direction tends to parallel the direction of the slip lines.

The action of cyclic stress above the endurance limit altered the direction of the Hartmann-Lueders lines observed on the 0.20% carbon steel when the damaged specimen is tested in tension. Instead of the general slip, that produces the lines, occurring on planes at 45° with the axis of the tensile specimen, the plane of slip became more nearly parallel to the axis.

The authors say "Cycles of repeated stress apparently have a tendency to orient the crystalline grains into a common direction of planes of maximum strength although this tendency is by no means fully effective. Thus metal subjected to fatigue damage might be expected to act somewhat like a single crystal."

The bulletin contains many micrographs showing the progress of slipping and cracking.

The methods used in this work might well be applied to the study of different classes of metals and alloys tested at different degrees of overstress or understress applied for varying numbers of cycles so as to find the quantitative effects more definitely than has been done in this preliminary survey.—H. W. Gillett.

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* H. F. Moore & T. Ver, *University of Illinois Engineering Experiment Station Bulletin* No. 208 *University of Illinois Bulletin*, Vol. 27, June 3, 1930, 60 pages.

A. S. S. T. Convention Sessions

Dr. Albert Sauveur, professor of metallurgy and metallography at Harvard University, has been announced as chairman of the meeting of the American Society for Steel Treating in Chicago, Wednesday morning, Sept. 24, during the National Metal Congress. The annual Campbell Memorial Lecture will be given at this time by Dr. M. A. Grossmann, Republic Steel Corp., Massillon, Ohio, who will discuss "Oxygen in Steel."

Others who have accepted chairmanships at the A. S. S. T. convention sessions are: H. W. Gillett, director, Battelle Memorial Institute, Columbus, Ohio; H. J. French, International Nickel Co., Bayonne, N. J.; Donald G. Clark, director of sales, Firth-Sterling Steel Co., McKeesport, Pa.; J. Fletcher Harper, Allis-Chalmers Mfg. Co., Milwaukee, Wis.; G. B. Waterhouse, Massachusetts Institute of Technology, Cambridge, Mass.; Jerome Strauss, Vanadium Corp. of America, Bridgeville, Pa.; C. H. Herty, Jr., U. S. Bureau of Mines, Pittsburgh; V. O. Homerberg, Massachusetts Institute of Technology, Cambridge, Mass.; E. C. Bain, U. S. Steel Corp., Kearny, N. J.

Vice-chairmen will be: Frances H. Clark, Western Union Telegraph Co., New York City; A. H. d'Arcambal, Pratt & Whitney Co., Hartford, Conn.; E. F. Cone, *The Iron Age*, New York City; R. S. Archer, Aluminum Co. of America, Cleveland; J. R. Adams, The Midvale Co., Nicetown, Philadelphia; V. T. Malcolm, Chapman Valve Mfg. Co., Indian Orchard, Mass.

Production of Metallic Cadmium in 1929

The production of metallic cadmium in the United States in 1929 amounted to 2,481,427 pounds, valued at $2,009,956, as reported by producers to the United States Bureau of Mines, Department of Commerce. This is an increase of 32 percent in quantity over the production of 1,875,896 pounds in 1928, which was 75 percent higher than production in 1927 and prior to 1929 the largest annual production on record. The average value reported by producers in 1929 was 81 cents a pound compared with 61 cents a pound in 1928. There were 214,307 pounds of cadmium, valued at $184,527, imported into the United States during 1929, compared with 233,101 pounds, valued at $128,901, in 1928.

There were five producers of metallic cadmium in 1929, American Smelting and Refining Co., Denver, Colo.; Anaconda Copper Mining Co., Great Falls, Mont.; Grasselli Chemical Co., Cleveland, Ohio; New Jersey Zinc Co., Palmerton, Pa.; and the U. S. Smelting, Refining & Mining Co., Midvale, Utah.

In addition to metallic cadmium, domestic manufacturers reported production of the following cadmium compounds in 1929: cadmium sulphide, cadmium sulphate, cadmium hydrate, cadmium oxide, cadmium chloride, cadmium acetate and cadmium lithopone. The estimated cadmium content of cadmium compounds produced was 433,300 pounds, valued at $498,734, in 1929, compared with 239,900 pounds, valued at $228,013, in 1928.

Translation

The readers of Metals & Alloys *will be assured of receiving in this section an extended abstract in English of the best articles appearing in foreign publications.*

A Contribution to the Problem of Precipitation Hardening of Iron*

By Walter Eilender, Aix-la-Chapelle, Germany & Roland Wasmuht, Essen, Germany

Recent researches of G. Masing[1] and W. Köster[2] showed that iron as well as certain other metallic alloys could be made to show a duralumin type of hardening. Quenching iron below the A_1 point with subsequent aging at room temperature or slightly higher, causes a substantial increase in the hardness. This effect was accompanied by a noticeable decrease in the notched bar impact resistance, in the elongation and the reduction of area. This phenomenon has been attributed to the highly dispersed precipitation of a component of limited solubility contained in the material, similar to the hardening of certain types of light metals.

Köster designates this effect in iron as "refining," since the terms "annealing," "hardening," "aging," have already assumed definitely accepted meanings in the metallurgy of iron. This effect, while increasing the hardness of iron, decreases its notched bar impact resistance, the elongation and reduction of area, so that correctly stated, there is no improvement of the physical properties of the iron. The effect is designated as "precipitation hardening," a term already proposed by R. S. Dean, R. O. Day and J. L. Gregg.[3]

The following are the conditions under which precipitation hardening may take place: 1. The solubility of the substance contained in solid solution in the base metal must decrease with decreasing temperature; 2. The amount of the substance absorbed in solid solution at higher temperatures must be retained in solution after quenching, that is, the alloy must be susceptible of undercooling; 3. On aging at room temperature or slightly above, an amount of the substance corresponding to the equilibrium conditions must be slowly precipitated out of the undercooled solution in highly dispersed form. According to Köster, this presupposes that the amount of the substance which does not enter into the solution at the quenching temperature in the phase of limited solubility is not contained in too finely divided dispersion in the base metal, inasmuch as this fine dispersion bars the undercooling by germination.

Both Masing and Köster attributed precipitation hardening in iron to the effect of carbon which possesses an increasing solubility with increasing temperature in α-iron. As has already been stated by Köster and Fry the precipitation hardening, of itself, may be produced by other substances, provided the above mentioned conditions are fulfilled.

The above requirements are fulfilled, among other materials, particularly by the systems iron–nitrogen and iron–oxygen. According to A. Fry,[4] there is present in solid solution in the iron-nitrogen system about 0.015% N, at 580° C. about 0.5% N. Consequently, between 0.015 and 0.5% N, these alloys should be susceptible of precipitation hardening. In the system iron–oxygen, an increase in temperature causes an increase in the solubility of oxygen, although the extremities of the solubility line are not accurately known. According to A. Wimmer,[5] P. Oberhoffer, H. J. Schiffler and W. Hessenbruch,[6] C. Benedicks and Löfquist,[7] W. Rosenhain, D. Hanson and Tritton[8] it may be assumed that at room temperature about 0.035–0.05% O is dissolved, while in accordance with more recent investigations by W. Krings and J. Kempkins,[9] at 715° C. about 0.10% is dissolved and according to R. Schenck, Th. Dingmann, P. H. Kirscht and H. Wesselkock[10] about 0.4–0.5% is dissolved between 800° and 1000° C.

Melts were produced, which on the one hand had increasing oxygen content with lowest possible and uniform nitrogen content, and on the other had increasing nitrogen content with lowest possible and uniform oxygen content. Furthermore, carbon, which according to Köster is susceptible of producing precipitation hardening, was kept as low and as uniform as possible in every instance. It is practically impossible to entirely eliminate undesirable ingredients, necessitating the use of a blank value, determined by the approximately constant influence of these ingredients. The melts used for the present investigations had an average carbon content of about 0.013% which according to Köster is apt to produce an increase in the hardening effect of about 10–15%.

Other factors capable of exerting a certain influence are: degree of deformation of the samples, with respect to hot working as well as to cold working; methods of producing the melts, etc. The effort was made to insure as great a degree of uniformity among the samples and melts as possible. The raw material used was Armco-iron of the following composition: 0.014% C, 0.02% Mn, trace of Si, 0.007% P, 0.050% S, 0.06% Cu. The material was melted in a high frequency furnace (Fig. 1) which permits melting in any desired atmosphere. The various oxygen contents were obtained by first remelting in an atmosphere of hydrogen whereby practically all oxygen was eliminated. Some of the melts were made in high vacuum either with or without the addition of small amounts of pig iron, whereby greater or lesser amounts of oxygen remained in the metal. The amount of pig iron added was such that the carbon introduced was sufficient for decreasing the oxygen content but insufficient to materially increase the carbon content. In order to obtain high oxygen contents, the Armco iron was merely remelted and air was blown through it. Melts having increasing nitrogen content were produced in the same manner, using pure dry ammonia gas, air being excluded. The hydrogen produced by the decomposition of the ammonia simultaneously decreases the oxygen content of the melt. By more or less intense treatments higher or lower nitrogen contents were

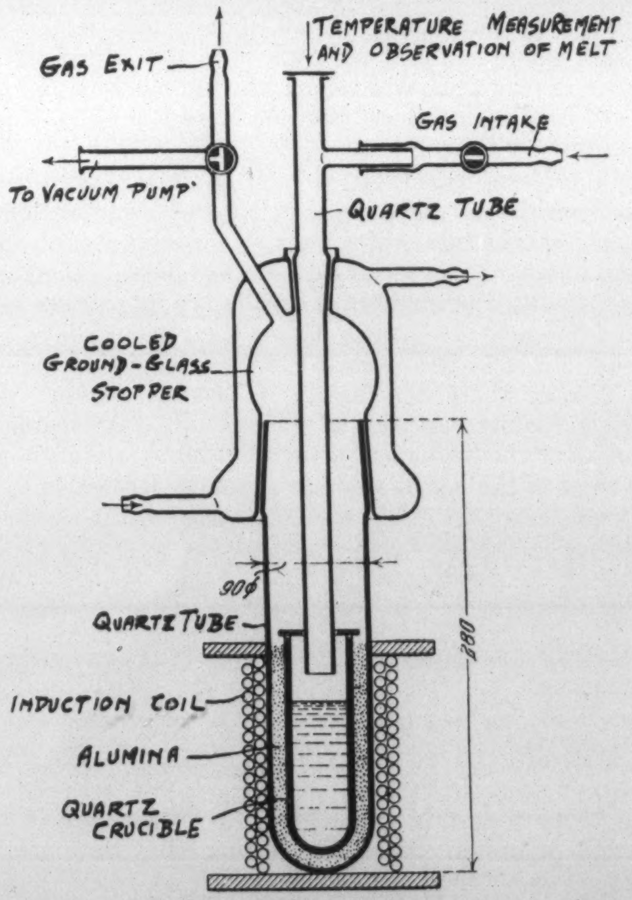

Fig. 1—Melting Apparatus

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* An Extensive Abstract of a translation of the original, which appeared in *Archiv für das Eisenhüttenwesen*, Vol. 3, April 1930, pages 659–664.

[1] *Archiv für das Eisenhüttenwesen*, Vol. 2 (1928–29), pages 185–196.

[2] *Archiv für das Eisenhüttenwesen*, Vol. 2 (1928–29), pages 503–522.

[3] Technical Publication 93, American Institute of Mining & Metallurgical Engineers.

[4] *Krupp'sche Monatshefte*, Vol. 4 (1923), page 137.

[5] *Stahl und Eisen*, Vol. 45 (1925), pages 73–79.

[6] *Stahl und Eisen*, Vol. 45 (1927), pages 1540–1543.

[7] *Zeitschrift für anorganische und allgemeine Chemie*, Vol. 171 (1928), page 231; *Jernkontorets Annaler*, Vol. 83 (1928), page 349.

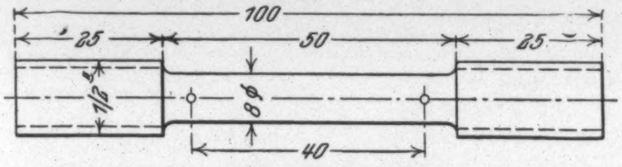
[8] *Journal Iron & Steel Institute*, Vol. 110 (1924), page 80.

[9] *Zeitschrift für anorganische und allgemeine Chemie*, Vol. 183 (1929), pages 225–250.

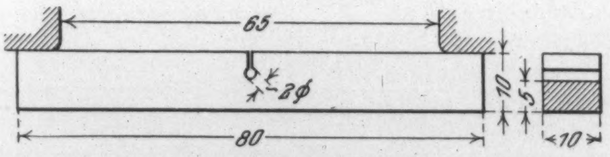
[10] *Zeitschrift für anorganische und allgemeine Chemie*, Vol. 182 (1929), pages 97–117; see also *Stahl und Eisen* Vol. 50 (1930), pages 18-19.

obtained. In this manner only about 0.04% nitrogen may be introduced into the material homogeneously. Higher contents were introduced by nitriding whereby owing to the inhomogeneous layers produced, the effect of precipitation hardening could be measured only in the outer zones. Samples of electrolytic iron were nitrided for 12 hours in a current of ammonia at 600°, 700° and 900° C., whereby nitrided layers of from 1.2 – 1.8 mm. depth and average nitrogen contents in the case of from 0.4–0.9% could be obtained. After normalizing at 950° C. these samples were subjected to precipitation hardening under the same conditions. Due to the thin cases the hardness could not be measured by the Brinell method, a Rockwell hardness tester with diamond point and 150 kg. load was used. Due to the different properties of the sublayers these values have only a qualitative character.

Carbon, nitrogen and oxygen determinations were made with all melts. The melts were forged to a 15 mm. square section, normalized at 930° C. for $^1/_2$ hour and slowly cooled in the furnace. Two notched bar impact tests were made with these rods, as well as two tensile tests, two oxygen analyses, micrographs and turnings for chemical analysis. The dimensions of the test pieces are shown in Fig. 2. To produce precipitation hardening, the samples were heated in an electric furnace for $^1/_2$ hour to the desired temperature and quenched in ice water. To ascertain the notched bar impact resistance and tensile strength, the first sample was tested immediately after the quenching, while the second was tested after varying periods of aging and under various conditions. The increase in hardness during the aging or drawing was followed with a Brinell tester and the notched bar impact test, in the beginning daily, later at greater intervals. Each hardness number is the average of 4 determinations taken at various points of the sample.



Tensile Specimen



Notched Impact Specimen

Fig. 2—Dimensions of Samples

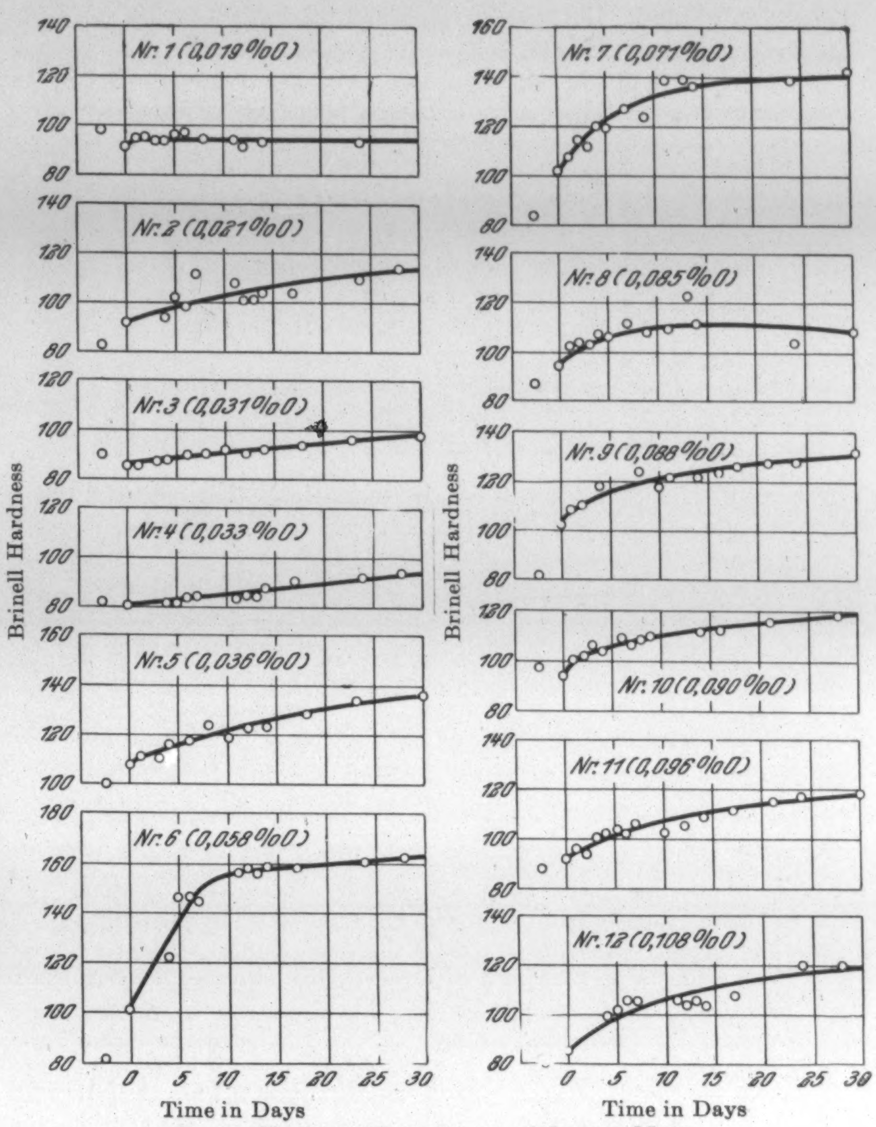


Fig. 3—Hardness-Time-Curves of Oxygen Melts

The Effect of Oxygen upon Precipitation Hardening.—Table 1 shows the composition of the melts with increasing oxygen content. After normalizing, the samples made from these melts were quenched at 680° and aged at room temperature while the hardness was continuously followed. After two weeks aging, the second notched bar impact test was made. The clearest picture of the changes in properties was furnished by the hardness measurements. The values obtained with the notched bar impact test were erratic. For this reason the following is based chiefly upon the hardness measurements. The samples showed, to a greater or lesser degree, capability of a precipitation hardening as is shown in Table 1 and Fig. 3. The melts lowest in hydrogen as a rule showed the least slope in the hardness-time curve. Up to contents of 0.04% O there are no striking dissimilarities. The most pronounced slope is shown by melts containing about 0.06% O, with higher contents the hardness curve flattens out. With 0.07% O an inordinate increase in hardness is indicated, while with samples containing from 0.08–0.13% the curve is almost parallel to that of the melts containing very little oxygen, although on the average slightly higher. If merely initial and final hardnesses are plotted with increasing oxygen contents, see Fig. 4, the difference indicates the increase in hardness (shaded areas) of the melts having varying oxygen contents. It is seen that the values gravitate around a mean value, whereas the melts containing 0.06 and 0.07% O give higher final values. With high oxygen contents the percent increase in hardness is on the average somewhat higher than with lower oxygen contents. In accordance with these results, it might be possible to assume a maximum increase in hardness of the material with an oxygen content of 0.06%. The precipitation hardening accompanying such low oxygen contents as up to about 0.04% is merely attributable to the effect of the carbon. Under the assumption that 0.04% O is soluble in iron, at room temperature, it is comprehensible that increasing oxygen contents up to about 0.04% have no effect upon precipitation hardening, since in these cases the solubility curve of oxygen during cooling is not intersected. The maximum hardening effect at about 0.06% O may be due to the fact that this value corresponds to the maximum solubility of oxygen at 680° C. With increasing oxygen contents, the precipitation hardness would decrease because in the present case the above mentioned third condition is not satisfied, that is, the excess oxygen content which does not enter into solution and is present in such subdivided form that the melts are no longer capable of undercooling. This would mean that during quenching the oxygen is eliminated by germination so that it has no pronounced effect upon the hardness. Since the occurrence of a maximum value had been observed only with two melts it was decided to check the values obtained. If it is assumed that these values are somewhat erratic then it would merely be possible to ascertain a very weak increase in precipitation hardness with increasing oxygen content, beyond that hardness which is caused by the carbon content. An unequivocal solution of this question would enable valuable fundamental conclusions with respect to the problem of the solution of oxygen in iron. It is impossible that in this series of experiments the nitrogen played any role in precipitation hardening. Likewise, the fluctuations in the carbon contents should not

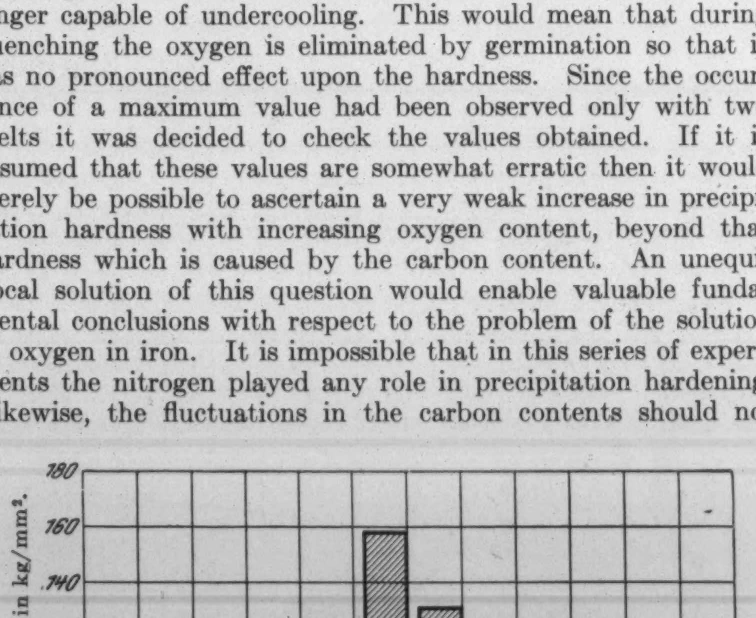


Fig. 4—Increase in Hardness after 14 Days' Storage

appreciably affect the results obtained, since these contents are very low and uniform.

Table 1
Composition and Hardness Change in Oxygen Melts Due to Precipitation Hardening

Sample	C %	N %	O %	Brinell Hardness in Kg./mm.^{2} Normalized	Quenched	Aged	Increase	% Increase
1	0.010	0.005	0.019	88.4	91.0	94	3.0	3.3
2	0.011	0.006	0.021	82.4	92.4	104	11.6	12.5
3	0.010	0.004	0.031	89.5	85.1	91.7	6.6	7.8
4	0.009	0.005	0.033	81.7	79.7	88.8	9.1	11.4
5	0.012	0.010	0.036	100.1	108.7	123.3	14.6	13.4
6	0.014	0.003	0.058	81.7	101.0	158.0	57.0	56.5
7	0.017	0.005	0.071	83.1	101.9	136	34.1	33.5
8	0.013	0.010	0.085	87.2	94.1	112	17.9	19.0
9	0.014	0.007	0.088	81	101.9	124	22.1	21.7
10	0.012	0.001	0.090	97.1	94.7	112	17.3	18.3
11	0.012	0.006	0.096	88.7	91.7	108	16.3	17.8
12	0.011	0.009	0.108	79.1	87.3	106	18.7	21.4

We may conclude from these investigations that generally speaking the oxygen content of a material has no material influence upon precipitation hardening except a critical value which at a quenching temperature of 680° C., would be at about 0.06% O. The condition in which the oxygen is present plays an essential role. It could readily be shown that if oxygen is present in the form of silicon dioxide, there would be no effect upon precipitation hardening since silicon dioxide does not enter into solution at the temperatures in question. The same applies to alumina. It is only the oxygen contained in ferrous oxide and manganous oxide that has any influence in that respect.

Effect of Nitrogen upon Precipitation Hardening of Iron.—In the case of nitrogen, the facts are simpler than with oxygen. That nitrogen is susceptible of producing precipitation hardening in iron has already been suspected by the American investigators Day, Dean and Gregg.[3] Melts with increasing nitrogen content were produced as described above. Precipitation hardening was produced by quenching at 680° C. and subsequent aging at room temperature (Table 2). The samples having a nitrogen content of 0.27% and more, after normalizing exhibited the characteristic nitrogen needles. After quenching at 680° C., these needles disappeared which indicates that the nitride had gone into solution. The determination of the increase in hardness was made in a manner similar to the oxygen samples; also the second notched bar impact tests were made after two weeks aging.

Table 2
Composition and Hardness Change in Nitrogen Melts Due to Precipitation Hardening

Sample	C %	N %	O %	Brinell Hardness in Kg./mm.^{2} Normalized	Quenched	Aged	Increase	% Increase
a	0.010	0.004	0.031	89.5	85.1	91.7	6.6	7.8
b	0.011	0.006	0.021	82.4	92.4	104.0	11.6	12.5
c	0.012	0.010	0.031	100.1	108.7	123.3	14.6	13.4
d	0.010	0.027	0.074	93.2	110.8	162.0	51.2	46.3
e	0.015	0.032	0.046	104.7	118.2	180.0	61.8	52.2
f	0.013	0.040	0.046	102.8	120.4	204.0	83.6	69.4

The hardness-time curves, Fig. 5, show that with nitrogen contents up to about 0.01%, there is no material increase in precipitation hardening, provided the curves have a slope so as to correspond to the precipitation hardening caused by carbon. With increasing nitrogen content a characteristically dissimilar trend of the curves becomes obvious. The increase in hardening takes place at a rapid rate, reaches a maximum after a few days, and retains the hardness imparted. With increasing nitrogen content, a notable increase of the rate of precipitation hardening is observed (Fig. 6). With increasing nitrogen content, the initial hardness increases, but the percent hardness increase is considerably enhanced with increasing nitrogen content (Fig. 7), which illustrates the increase of the percent hardness increase with augmenting nitrogen contents. Up to nitrogen contents of 0.1%, the values scatter around a value of about 12%, which probably corresponds to the average carbon content, and then consistently increase with increasing nitrogen content. In accordance with the diagram by Fry about 0.015% N is dissolved at room temperature, therefore it will not be possible to obtain any precipitation hardening up to this point, since the solubility curve is not intersected. Beyond this point it is likely that nitrogen contents up to 0.5% N will produce increasing precipitation hardening with increasing nitrogen content, an effect which it was possible to accurately follow up to 0.04% N. Since higher nitrogen contents are not obtainable with an even distribution in the material, it was attempted to approximately ascertain the further trend with nitrided samples. The samples showed a further pronounced increase in hardness in the outer zones with nitrogen contents of from about 0.4 to 0.9% (Table 3 and Fig. 8). We wish to emphasize, however, that these values constitute only an approximation to the real value, since the nonuniform depth of case barred any accurate measurement or conclusion.

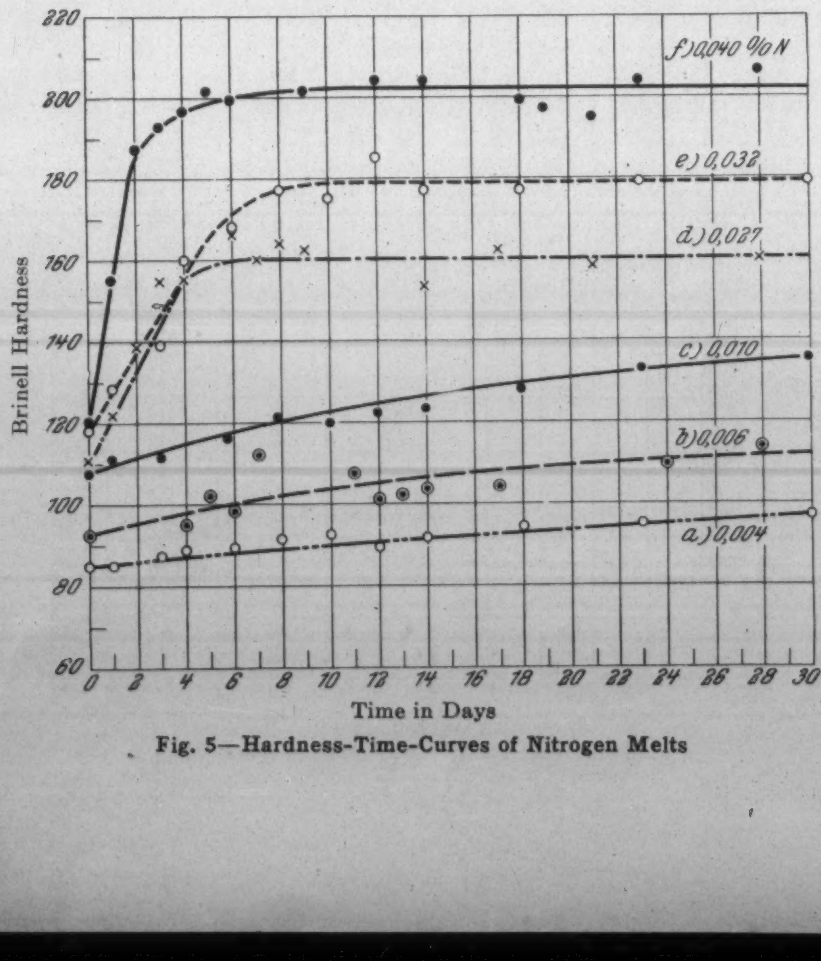


Fig. 5—Hardness-Time-Curves of Nitrogen Melts

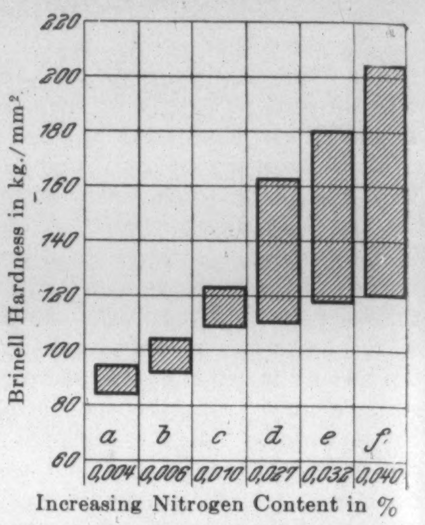


Fig. 6—Increase in Hardness after 14 Days' Storage

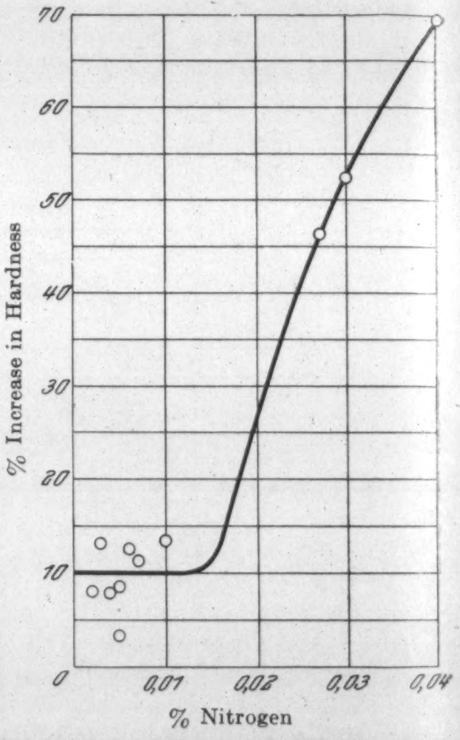


Fig. 7—Percent Increase in Hardness with Increasing Nitrogen Content

Table 3
Treatment and Properties of Nitrided Electrolytic Iron Samples

Sample	Nitriding Time hrs.	Nitriding Temp. ° C.	Total Depth Nitrided Layer mm.	Average N Content of Nitrided Layer %	Increase in Hardness after 14 Days Storage at 20° after Quenching at 680° C kg./mm.^{2}	%
g	12	600	1.2	~0.4	135	81.8
h	12	700	1.83	~0.5	160	89
i	12	900	1.50	~0.6	144	86.7
k	12	900	1.42	~0.9	190	65.6

Tensile tests made with a few specimens did not furnish anything remarkable. Judging from the aspect of the fracture, however, the effect of the precipitation hardening was noteworthy. Fig. 9 shows the tensile bars containing 0.032% N. The two specimens were taken directly next to each other from the forged test bar. Specimen 1 was tested immediately after quenching at 680° C., Specimen 2 after 2 weeks aging. Specimen 1 showed a remarkable elongation and reduction of area while the same specimen had become brittle after two weeks aging without having experienced any material increase in tensile strength. The tensile values are given in Table 4.

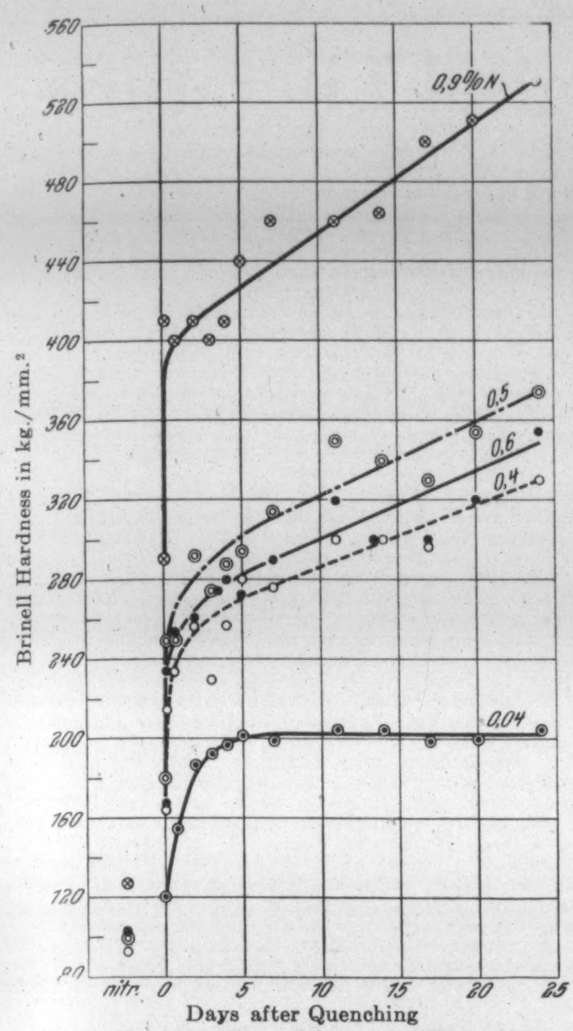
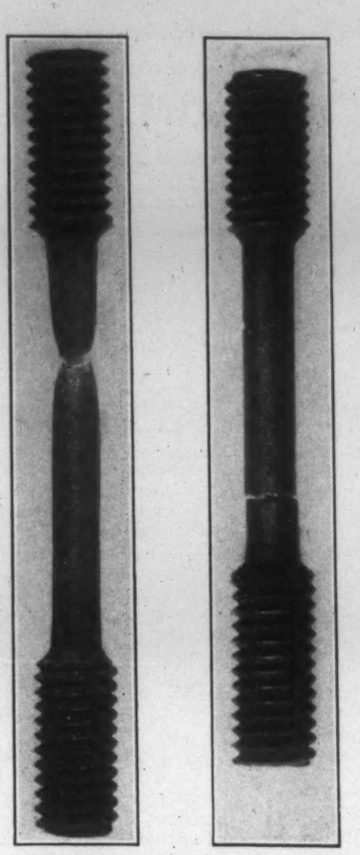


Fig. 8—Hardness-Time-Curves with Higher Nitrogen Content in Edge Zones (by Nitriding)



Sample 1 Sample 2

Fig. 9—Tensile Test of Melt with 0.032% Ni

Sample 1: Tested immediately after quenching.
Sample 2: Tested after 14 days' storage.

These results show that the dissolved nitrogen cannot be said to have caused the hardness and brittleness of the nitrided material as is the case with the nitrogen precipitated out in highly dispersed form.

Table 4
Change in Physical Properties of Melt e with 0.032% N after 14 Days Storage at 20° after Quenching at 680° C.

Tensile Strength				Elongation				Reduction of Area			
Quenched	14 Days Storage	Increase		Quenched a	14 days Storage b	Decrease a—b		Quenched a	14 Days Storage b	Decrease a—b	
%	%	%	%	%	%	%	%	%	%	%	%
39.1	44.8	5.7	14.6	33.0	2.7	30.3	91.8	61.0	2.5	58.5	96.0

Influence of Drawing Temperature upon the Oxygen and Nitrogen Precipitation Hardening.—To ascertain the effect of drawing temperature upon the degree of precipitation hardening, a sample of the oxygen series having experienced an abnormal precipitation hardening and containing 0.071% N were drawn for several days at different temperatures. Previous to that treatment, the samples had been quenched at 680° C. in ice water. In both cases (Fig. 10 and Table 5), aging at room temperature, causes the maximum hardness obtainable. It is true that the maximum value is obtained only after a relatively long time. With increasing drawing temperatures, the maximum hardness is obtained in a shorter time, while the maximum value obtainable is decreased with increasing drawing temperature. At 100° C. drawing temperature the maximum value obtainable is very low, but is already attained after 4 hours, whereupon it falls rapidly to the initial value. This phenomenon agrees with Köster's observations who observed precipitation hardening caused by carbon.

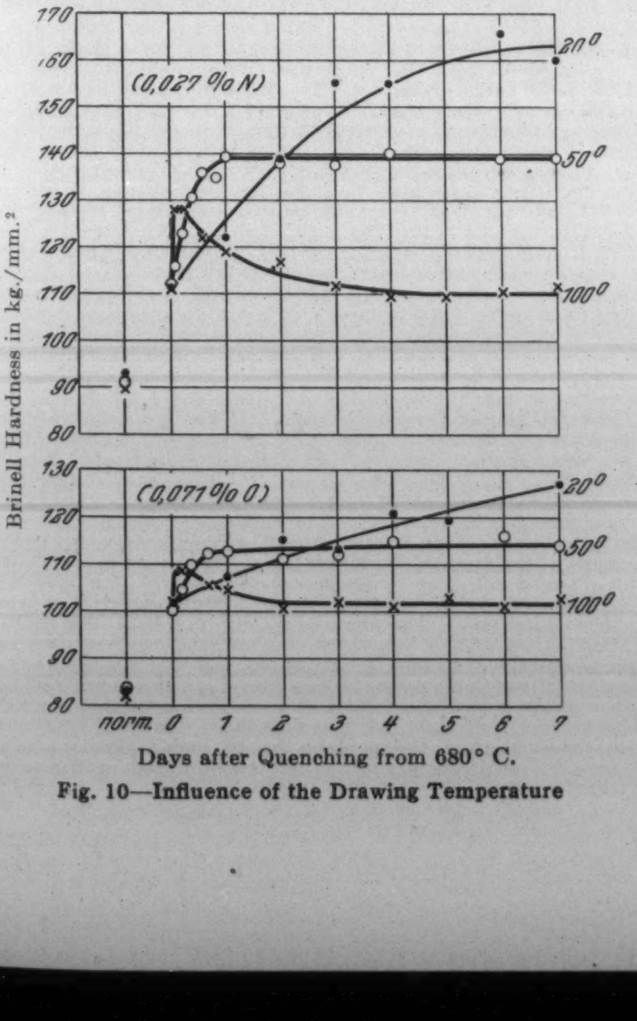


Fig. 10—Influence of the Drawing Temperature

Investigations into the Precipitation Hardening of Bessemer and Open Hearth Steels.—In addition to the experiments with synthetic melts, experiments were made with 32 Bessemer and Open Hearth heats in order to ascertain the effect of carbon, oxygen and nitrogen within the limits of contents encountered in steel making practice. The composition of the samples: Carbon between 0.13 to 0.17%, nitrogen of the Bessemer melts 0.008–0.015%, of the Open Hearth melts 0.004–0.006%. The oxygen contents[11] fluctuated between 0.005 and 0.017%, without material differences between Bessemer and Open Hearth melts. On the average the Open Hearth melts had a slightly lower oxygen content. The samples were treated as described above. With all samples, the effect of precipitation hardening was more or less noticeable. In order to ascertain which of the components in question was responsible for the degree of the hardening, the results of the physical tests were arranged in accordance with the carbon, nitrogen and oxygen contents of the samples.

In considering the data from the standpoint of carbon content, a tendency to a decrease of the physical property changes with increasing carbon content is noticeable. This observation would tally with the results obtained by Köster, since we are considering the carbon contents upon the falling branch of the hardness increase-carbon content curve. No material difference between Bessemer steel and Open Hearth steel is noticeable. The initial hardness and tensile strength of the Bessemer steel is somewhat higher on the average than that of the Open Hearth steel, presumably owing to the higher nitrogen content. The percent physical property changes are the same in both steels.

If the values obtained are arranged in accordance with the nitrogen content, there is still no relation of the physical properties to the nitrogen content. Only the absolute values of the initial hardness and the tensile strength showed an increase with increasing nitrogen content, wherein a noticeable deviation of the Bessemer melts may be seen. This result was to be expected since none of the samples showed more than 0.015% N. As is shown by the diagram, the nitrogen contents below about 0.015% N are not susceptible of producing precipitation hardness since they are located below the limit of solubility of nitrogen in α-iron at room temperature. The increased hardness of the samples is merely due to the carbon content.

The same result was obtained by arranging the melts according to their oxygen content. It was shown that a content of 0.017% O, practically an average in Bessemer and Open Hearth steels, does not produce a modification in the mechanism of precipitation hardening.

Table 5
Change in Brinell Hardness after Storage for Different Periods at Different Temperatures

Material	Melt with 0.071% O			Melt with 0.027% N		
Drawing Temperature	20°	50°	100°	20°	50°	100°
Normalized	83.0	83.7	82.4	93.2	91.0	90.3
Quenched from 680°	101.9	100.1	101.0	110.8	111.8	110.8
After 2 hrs.	...	101.9	105.2	...	116	128
" 4 "	...	...	104.7	...	...	124.7
" 5 "	...	107.1	...	...	123.3	...
" 6 "	...	...	108.4	...	...	128
" 9 "	...	109.8	104.7	...	130.5	127
" 14 "	...	111.8	105.8	...	136	122
" 19 "	...	111.7	...	...	134.7	...
" 1 day	107.7	112.7	104.7	122	139	119.3
" 2 days	115	110.7	100.4	139	137.5	117
" 3 "	112.9	111.8	102.1	155	137.5	111.7
" 4 "	120.4	115	101.2	155	140.3	109.7
" 5 "	119.3	...	102.7	...	...	109.7
" 6 "	...	116	101.2	166	139	110.7
" 7 "	127	113.9	102.7	160	139	111.7

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[11] Oxygen determination by the carbon reduction process.

Abstracts of Current Metallurgical Literature

These abstracts are not critical, but merely review developments as they are recorded. Beginning with this issue the various classifications are numbered. This number is at the end of each abstract and will be of assistance in mounting them on cards for filing.

WORKING OF METALS & ALLOYS (12)

Melting & Refining (12a)

Production of Quality Steels in the Coreless Induction Furnace. (Die Erzeugung von Edelstählen im Kernlosen Induktionsofen.) O. Dörrenberg & N. Broglio. *Stahl und Eisen*, Vol. 50, May 8, 1930, pages 617-626.

Report No. 183 of the Steel Mill Committee of the Verein deutscher Eisenhüttenleute. Including discussion. The development and theoretical principles of the induction furnace are briefly considered. Then follows a detailed description of the high frequency furnace and additional equipment installed at the Ründeroth Steelworks of E. Dörrenberg Söhne. The factors influencing the power consumption, as for instance, size and chemical composition and electromagnetic properties of the charge, are especially dealt with. The efficiency amounts on the average from 78–80%. The average power consumption for melting the cold charge is 600 KWH per ton. The total power consumption before the melt is poured amounts to 720–790 KWH per ton. The melting time, including charge and pouring, is 92 minutes on the average. The melting time varies with the type of the melting. The average weight of a melt is 285 kg. The metallurgical melting process is compared with the crucible process. The advantages offered by the possibility of an unlimited heating without taking care of the possible destruction of the crucible are stressed. The influence of a good mixing of the melting bath, taking into consideration the composition of various kinds of steel, was especially investigated. The favorable influence offered by this careful mixing of the bath is proved above all for steels containing free carbides. Besides economical advantages an essential improvement of a great number of steels was found. GN(12a)

Spring Steel by the Soft Process. *Mainspring*, Vol. 3, Feb. 1930, 3 pages.

Describes in an informal way the method of making spring steel by the "softprocess." MLM(12a)

Modern Steel Making. *Mainspring*, Vol. 3, Jan. 1930, 3 pages.

Very brief statement of the way our high-grade steels are made. MLM(12a)

The Effect of Melting Conditions on the Microstructure and Mechanical Strength of Gray Cast Irons Containing Various Amounts of Carbon and Silicon. A L. Norbury & E. Morgan. *Journal Iron & Steel Institute*, May 1930, Advance Copy 11, 20 pages. *Engineering*, Vol. 129, May 16, 1930, page 643.

This paper gives the results of an investigation into certain phases of melting conditions, including the effect of superheating, additions of steel, silicides, graphite, gases and iron oxide on the microstructure and mechanical strengths of gray cast iron. See *Metals & Alloys*, Mar. 1930, page 429. LM & AEH(12a)

The Physical Chemistry of Steel Making, Deoxidation of Steel with Aluminum. C. H. Herty, Jr., J. M. Byrns & G. R. Fitterer. *Iron & Coal Trades Review*, Vol. 120, Mar. 7, 1930, page 431.

Describes one phase of the work on Inclusions in steel carried on by the Bureau of Mines, Carnegie Institute of Technology and 43 firms in the steel industry. See *Metals & Alloys*, June 1930, page 568. RHP(12a)

Electric Furnace Iron. G. L. Simpson. (Pittsburgh Electric Furnace Corp.) *Preprint* 57-12, *American Electrochemical Society*, May 29-31, 1930, pages 133-138.

In the application of electric furnace processes to the production of gray iron, decided advances have been made during the past eight years. In the continuous duplexing process described, the metal is melted in the cupola, with just as little coke as will make it run properly, and is then transferred to the electric furnace. In the preferred continuous melting process a cold charge is melted directly in the electric furnace, and, as soon as composition is corrected and the temperature is high enough, part of the molten metal is tapped, and immediately thereafter the equivalent amount of cold metal is charged. This process is of decided commercial importance. At one of the plants 11 tons of gray iron is being tapped every hour. The process has a wide field of application. (12a)

On the Decarburization of Iron in the Open Hearth Furnace and the Concentration of Free Ferrous Oxide in Basic Slags. (Ueber die Entkohlung des Eisens im Siemens-Martin-Ofen und die Konzentration des freien Eisenoxyduls in basischen Schlacken.) H. Schenck. *Archiv für Eisenhüttenwesen*, Vol. 3, March 1930, pages 571-576; *Krupp'sche Monatshefte*, Vol. 11, Feb.-Mar. 1930, pages 39-46.

The author describes investigations which he carried on to determine if there is a relationship between the content of ferrous oxide in the slag and the carbon content of the steel. Results of investigation from seven 20-ton open-hearth melts by F. Körber and seven more 60-ton melts on which the author made measurements were evaluated. The results are summarized as follows: It was determined at first if the conclusion drawn from the theory is correct, that there exists a relationship between the carbon content of the metal and the concentration of free FeO. Various opinions on the value of FeO are discussed. A relationship between carbon content and concentration of FeO exists only under the condition that part of the iron which is contained in the slag is considered to be bound to CaO in the form of lime-ferrite. The formulae derived in a preceding report on the quantity of free FeO proved to be valuable in a similar way for the reactions of carbon in the 20-ton and 60-ton open-hearth melts evaluated in this report. It is probable that these formulae are qualified to judge the melting process which is of importance for the quality of a steel. GN(12a)

Investigations on Desulphurization and Oxidation in the Basic Steel Processes. (Untersuchungen über die Entschweflungsvorgänge und die Sauerstoffaufnahme des Metalls bei den basischen Stahlerzeugungsverfahren.) H. Schenck. (Friedrich Krupp A.G. Essen.) *Archiv für Eisenhüttenwesen*, Vol. 3, May 1930, page 685-692; *Krupp'sche Monatshefte*, Vol. 11, May 1930, pages 101-112.

Report No. 184 of the Steel Committee of the Verein deutscher Eisenhüttenleute. The data, obtained in the former investigation on the manganese, phosphorus and carbon reactions in steel process were used to determine the equilibrium of the sulphur reactions and its best efficiency. The observation checks satisfactorily with the calculation in spite of possible errors from sampling and analysis. The law of desulphurization as found, therefore, might undergo certain corrections. The influence of Mn, Al_2O_3 and MgO is discussed. Since the results permit one to draw the conclusion that the formerly developed function for determining free FeO is correct, the solubility of oxygen in the metal bath was calculated for various conditions of slag and temperature. The results could not be checked because of a lack of correct data. GN(12a)

Study Furnace Reactions. Hermann Illies. *Foundry*, Nov. 1, 1929 Vol. 57, pages 922-924.

Abstract of article in *Giesserei*, Mar. 30, 1928. A description of the salient points of the oil-fired furnaces, and results obtained are given. Generally charged with 50% hot iron from blast furnace and 50% iron from the cupola, which is almost entirely composed of scrap. Sulphur never exceeds 0.06%. Test bars were cast every 15 min. Results of experiments showed that superheating of iron with high phosphorus content in an oil-fired reverberatory furnace increases bending strength up to 40%. It also increases tensile strength, Brinell hardness and sp. gr. Temperature of 1400° C. should be maintained. Tabulates results of tests. VSP(12a)

Development of Electric Zinc Melting Process. W. R. Manny & William Adam, Jr. *Metal Industry*, N. Y., Mar. 1930, Vol. 28, pages 118-120.

Describes process used by the Atlantic Zinc Works, Brooklyn, N. Y. The process consists of casting suitable zinc slabs, and after inspection they are annealed, being maintained at uniform temperature for 24 hours, and then rolled. Ajax-Wyatt induction furnace has been used for melting zinc, which proved to be very satisfactory. Zinc is poured directly into the mold. Some of the advantages of the furnace are: (1) Improved product; (2) Lower metal losses; (3) Lower maintenance and labor costs, and (4) More uniform production. VSP(12a)

The Contamination of Aluminum Scrap. Robert J. Anderson. *American Metal Market*, April 26, 1930, Vol. 37, pages 4, 10; April 29, 1930, pages 4, 10; April 30, 1930, page 4, 10.

The increasing use of aluminum and its alloys has made the problems of the dealer and remelter of aluminum scrap more complex, but this has been met and secondary metal and aluminum alloys are now procurable of better quality than ever before. Ten classes of scraps are: (1) castings, (2) new clippings, (3) old sheet, (4) wire and cable, (5) spinnings, (6) foil, (7) spatters, (8) grindings, (9) borings and (10) drosses. These classes are subdivided. The three chief purchasers of aluminum and aluminum alloys are: (1) secondary remelters, (2) jobbing foundries, interested mainly in heavy castings scrap, but also in old sheet, and (3) rolling mills, interested mainly in new clippings and old sheet commercially pure. The analyses are given of several commonly used new aluminum alloys. Sources of contamination are discussed and stress made of the importance of alertness in detecting these. WHB(12a)

Melting Practice for Three Types of Electric Steel. H. P. Rassbach. *Fuels & Furnaces*, Oct. 1929, Vol. 7, pages 1563-1655.

From paper before American Society for Steel Treating, Sept. 9-13. See *Metals & Alloys*, Jan. 1930, Vol. 1, page 344. MS(12a)

Distinction between Solid and Molten Pig Iron Charges in Open-Hearth Furnaces. (Der Unterschied zwischen festen und flüssigen Roheisenersatz im Siemens-Martin-Ofen.) E. Killing. *Stahl und Eisen*, Dec. 19, 1929, Vol. 49, pages 1821-1827; Abstract Translation in *Foundry Trade Journal*, Feb. 13, 1930, Vol. 42, page 120.

Includes discussion. The results of the investigation show that charging molten pig-iron gives a better tonnage-hour output than with solid pig iron. The most favorable output is obtained for the liquid charge with 35% pig iron and for the solid charge with 19% pig iron. The ore consumption is less with solid than with liquid charges. The slag quantity is always higher with molten charges. Iron loss, on the average, is higher with liquid than with solid charges. Up to 62% pig iron the liquid charge process is more economical than the solid charge process. The investigation shows that in spite of the higher iron loss and the higher ore consumption the liquid charge process is more economical. Only a special investigation could decide the possibility if, by using a pig iron with lower phosphorus content, the slag quantity and the iron loss could be decreased about to the figures for the solid charge process. GN&VSP(12a)

Casting & Solidification (12b)

On the Inverse Ingot Segregation. (Ueber die umgekehrte Blocksiegerung.) W. Fraenkel & W. Gödecke. *Zeitschrift für Metallkunde*, Oct. 1929, Vol. 21, pages 322-324.

Experiments were carried out with the following alloys: Al-Cu with approximately 3 and 11% Cu, Ag-Cu with approximately 90% Ag and Zn-Cu with approximately 12% Cu. After casting into a chill heavy-walled iron mold, the Cu-Al alloys showed inverse segregation with the Cu concentrated on the outside. Analyses from top and bottom did not disclose gravity segregation in the Ag-Cu alloys but a slight inverse segregation was noticed from side to center of the ingot. A slight concentration of Zn on the side walls and a gravity segregation of Cu was found in the Cu-Zn alloys. By special experimental devices the crystals forming first were separated and investigated in the Al-Cu alloys resulting in the disclosure of a normal segregation. The influence of the wall thickness of the mold was investigated yielding an inverse segregation in the thick-walled mold. It is concluded that the first segregation is always normal and that inverse segregation results from a secondary process which takes place later during the process of solidification. A somewhat porous shell of the first solidification was confirmed by density measurements. Inverse segregation, due to a contraction on solidification producing a vacuum between the first formed crystals which draws in still fluid metal, is confined to the extreme outside layers. It was furthermore proved that in those layers closely below pipe-holes a composition prevails approaching the composition of crystals which are forming first in the solution according to the constitutional diagram, and finally that gases have nothing to do with inverse segregation as shown by vacuum melting. EF(12b)

The Laws of Linear Crystal Growth. (Ueber die Gesetze des linearen Kristallwachstums.) Georg Masing. *Wissenschaftliche Veröffentlichungen aus dem Siemens-Konzern. VIII Band. Zweites Heft*, June 27, 1929, pages 144-156

Includes bibliography of 16 references. Contains 5 illustrations. The author purposes to advance the knowledge on crystal growth in metals and alloys by clearing up a few current misconceptions by setting forth some original fundamental considerations. He aims to establish further proof for Tammann's laws of linear crystal growth with special reference to the temperature range covering the maximum speed of crystallization. The author states that Tammann's assumption that the melting point temperature exists at the boundary of a crystal which grows in the surrounding medium is only an approximation, but is of an accuracy sufficient for many practical applications. The fact that the temperature existing at the boundary between crystal and surrounding melt only approximates the melting point and does not coincide therewith is of fundamental importance, for it enables the explanation of many effects accompanying crystal growth, particularly such as are encountered in the solidification of cast metal ingot. AJM(12b)

Casting & Solidification (12b)

Why Ingot Molds Have Short Life. J. H. Hruska. *Iron Age*, Vol. 123, Feb. 21, 1929, pages 539–541.

The author gives the results of chemical analysis and hardness tests taken across the section of an ingot mold which had given 118 heats. A considerable oxidation of carbon, silicon, and manganese was found on the inside face of the mold and some oxidation on the outside surface. The inside surfaces were found to be harder than the center core and the outside surface. The author recommends a decrease in the size of graphite flakes by use of chromium or other means. (12b)

The Cooling Rate of Ingots from Casting to the Blooming Mill. (Die Abkühlung des Blockes vom Guss bis zur Blockstrasse.) W. Heiligenstaedt. *Archiv für Eisenhüttenwesen*, Vol. 3, May 1930, pages 709–716.

Report No. 138 of the Heat Committee of the Verein deutscher Eisenhüttenleute. Except macroscopic and microscopic structure of an ingot, the temperature and the uniformity of the temperature over the cross-section are most important for the rolling process. The cooling time of the ingot in the mold, the time of transportation of the stripped ingot and the soaking time in the pits have their bearing on the structure. The importance of the cooling time in the molds, the transportation time on the ingot temperature and the influence of the soaking pits are especially stressed. The importance of the wall thickness of the molds on the cooling process is also dealt with. GN(12b)

The Corner Ghost in Steel Ingots. Soji Maita. *Iron & Steel Institute*, May 1930, Advance Copy 9, 16 pages.

The nature of "ghost marks" or "ghosts" has been investigated by the author. "Corner ghosts" are usually found at corners of polygonal ingots but they are also found in round ingots. They result from rapid cooling of the steel during the formation of the external crystal zone from the molten metal. The mechanism of its formation is as follows: rapid cooling gives rise to some deformation in the external crystal zone, and creates in it an internal loose structure or fissure, which is then filled up with fluid segregate; such an occurrence may be accelerated by conditions inherent in the ingot body and its composition. Furthermore, some corner concentrated segregation may sometimes develop spontaneously. AEH(12b)

Bottom-Pour Electric Babbitt Pot With Heated Valve and Spout. *American Metal Market*, Vol. 37, June 10, 1930, page 3.

The Harold E. Trent Co., Philadelphia, Pa. is equipping its new electric melting pots with bottom spouts and positive-action valves. All parts of the control mechanism and the heating elements are outside of the crucible. Attached to the pot housing is an automatic temperature controller. WHB(12b)

How to Secure Best Conditions for Pouring Steel Ingots. F. Pacher. *Iron Age*, Vol. 125, Mar. 27, 1930, page 920.

Abstract translation of article in *Stahl und Eisen*, May 2, 1929. See *Metals & Alloys*, July 1929, page 28. VSP(12b)

Rolling (12c)

The Rolling of Aluminum Structural Shapes. *Metal Industry* (N. Y.), Vol. 28, Mar. 1930, pages 121–123.

Describes installation of a large blooming and structural mill for the United States Aluminum Co. at Massena, N. Y. Complete line of Al alloy structural sections, flats, squares and rounds are rolled. Gives a complete description of the plant and appliances used. VSP(12c)

On The Piercing Process in the Stiefel-Rolling Mill. (Ueber den Lochvorgang im Stiefel-Walzwerk unter besonderer Berücksichtigung der Beanspruchung und des Verhaltens des Lochstopfens.) F. Körber & K. Simoneit. *Mitteilungen Kaiser Wilhelm Institut für Eisenforschung*, 1929, No. 21, Vol. 11 (Report No. 139), pages 353–371.

The problem is considered from the mechanical and metallurgical viewpoints. GN(12c)

The Sticking of Sheets. (Das Kleben von Feinblechen.) W. Titze. *Stahl und Eisen*, June 20, 1929, Vol. 49, pages 897–903. *Iron Age*, Vol. 125, Mar. 13, 1930, page 795.

The sticking of sheets during rolling was investigated with 3 different types of steel, namely, steels with Ti content, without alloying elements and with copper content. The results prove that sticking is due to oxygen in steel in the form of FeO. The best means to decrease oxygen is boiling down of the melt for about 20 minutes to 0.20–0.25% C after adding the last additions of ore. The thoroughness of the deoxidation is best tested by hardened bending tests and the red shortness test. In case the steel fails in these tests the melt should be deoxidized again in the furnace. The addition of Ti and Cu is advisable for plates under 0.55 mm. Ti should be preferred for sheets for deep drawing purposes in consequence of the favorable influence of Ti on the deep drawing qualities. A high rolling temperature, at least 1250° C. at the blooming mill, is of importance in order to weld blow holes. Though there is no great difference in the behavior of the various parts of the ingot, the upper part, because of possible segregations, should only be used for low grade products. Top parts of ingots tend to stick. The relations between oxygen content, welding practice, respectively, and the degree of sticking are presented in diagrams. The results are discussed. In general the higher the oxygen content the more decided the tendency for sticking. VSP & GN(12c)

Rolling Aluminum Joists. *Engineer*, Vol. 149, May 9, 1930, page 523.

Briefly describes a process of producing rolled aluminum joists, channels and angles. LM(12c)

Tin and Sheet-Mill Rolls. Their Treatment, Performance and Premature Failure in Service. Eric R. Mort. *Journal Iron & Steel Institute*, May 1930, *Advance Copy* 10, 20 pages.

This paper gives the operating results of sixteen hot-mills of the single stand type and includes a brief review of the history of rolls used in tinplate works in the South Wales district. The author gives data regarding defects, working temperatures and performance. Among causes of premature failure he lists fractures leading to complete breakage, cracked body, spalling, shot-holes, mottle, chill fracture, damage caused by tongs and breakages. The author believes atmospheric conditions have little to do with roll breakages. AEH(12c)

The Rolling of Metals. J. Selwyn Caswell. *Engineer*, Vol. 149, Feb. 28, 1930, pages 232–234; March 7, 1930, pages 260–262; March 14, 1930, pages 288–289; March 21, 1930, pages 316–318; March 28, 1930, pages 342–344; April 4, 1930, pages 369–371, 387; April 11, 1930, page 403.

Discusses plasticity, the property upon which all metal working processes depend. Outlines modern theories regarding effect of applied stress on the behavior and properties of metals. Considers characteristics of the rolling mill as a deforming tool, discussing the movement and the deformation of the stock between the rolls in relation to the simple processes of compression and extrusion. Deals separately with numerous factors which differentiate flow in the mill from that which occurs in simple compression. Discusses energy requirements from first principles and in relation to ideal conditions. Considers subject of friction. Develops general energy equation for practical use and attempts to indicate its utility by applying it to actual rolling data comparing results with measured values of energy requirements in the mills. Gives numerous footnote references. Comprehensive, theoretical study of subject. Letters commenting on this article are given on page 387 of the April 4, 1930 issue and on page 403 of the April 11, 1930 issue. LM(12c)

(e) Shearing & Punching

Applying Stellite to Trimming Dies. Charles E. Harriman. *Machinery*, Mar. 1930, Vol. 36, page 550.

Dies made from mild steel with stellite cutting edges are cheaper and more easily made than carbon steel dies. There is no loss in hardening and no warping to contend with. Stellite is welded to the die so either old or new dies may be made in this way. Dies constructed in this way last about ten times as long as carbon steel dies. RHP (12e)

Chart for Determining Blanking Pressures for Mild Steel. B. J. Stern. *Machinery*, Mar. 1930, Vol. 36, pages 548–549.

Gives a chart providing a simple means for determining the pressure required to operate a blanking or piercing die. It is of value to the foreman in assigning dies to presses having sufficient capacity to avoid breakage. RHP (12e)

(g) Machining

Improved Methods of Finishing Bearings for Camshafts. Charles O. Herb. *Machinery*, Mar. 1930, Vol. 36, pages 526–529.

Describes methods and machinery used in the shops of the Packard Motor Car Company at Detroit. Special machinery and the substitution of milling for boring has made possible a considerable saving of time. RHP (12g)

Workability of Materials. (Bearbeitbarkeit von Werkstoffen.) *Zeitschrift Vereins deutscher Ingenieure*, Oct. 19, 1929, Vol. 42, pages 1527–1529.

The conception of the workability, the suitability for machining, of a material is not yet an entirely unambiguous conception. To find a reliable expression it is discussed for machining where a chip is cut off (1) what cutting depth must be used, (2) what feed can be given, (3) what cutting speed is permitted to dull the tool only after a time recognized as economical. In a similar way turning of a material is investigated. In Germany curves are given for the standardized tools which show the results of comparative tests. From these curves, standard times are derived giving the permissible feed and speed for a definite standard time, for instance one hour. It is recommended that this investigation be extended to other processes. HA(12g)

Machinability of Cast Steel Compared with Construction Steels. (Die Zerspanbarkeit der Stahlgusssorten im Vergleich zu den Baustählen des Maschinenbaus.) A. Wallichs. *Stahl und Eisen*, April 3, 1930, Vol. 50, pages 448–450.

The influence of the following factors on the machinability of cast steel was studied: Physical properties, melting process in open-hearth furnace, electric furnace or converter, carbon content, nickel and its influence on the heat treatment, Cr and Ni together and influence on heat treatment, phosphorus and sulphur content, silicon content, state of cast skin. Certain laws between some of these factors could be found: the opinion that the tensile strength is, generally spoken, an indication of the machinability of a steel, is confirmed. Machinability does not depend so much upon composition and structure of a steel. The results of a great variety of steels could be located all on one curve, plotting machinability against tensile strength. GN(12g)

Sawing 16″ Treated Armor Plate. Henry B. Allen. (Henry Disston & Sons, Inc.) *Carboloy*, Vol. 2, April 1930, pages 2–9.

Describes cutting of armor plate 16″ thick, 9 ft. across and 17 ft. long. Numerous tables showing results of tests are given. MLM(12g)

Machining Stainless Steel. J. H. Barber. *Metallurgia*, Vol. 1, Dec. 1929, pages 75 & 77.

In the early days of Staybrite, some difficulty was experienced in turning, drilling, milling, etc., but by means of slight modifications in tools and procedure these have now been entirely overcome and machining can be most satisfactorily accomplished. The essential factors for obtaining a good cut are: (1) Rigidity of the material being treated; (2) Rigidity of the machine tool; (3) Rigidity of the cutting tool; (4) The use of a suitable cutting tool, which must be made from good quality high speed steel. The article contains recommendations on speeds of turning, drilling, milling and filing and on sizes for tapping. (12g)

The Surface Condition of Materials in Machining, Especially Turning. (Das Oberflächenaussehen bei der spanabhebenden Bearbeitung, insbesondere beim Drehen.) F. Rapatz. *Archiv für Eisenhüttenwesen*, Vol. 3, May 1930, pages 717–720.

Report No. 163 of the Material Committee of the Verein deutscher Eisenhüttenleute. Including discussion. Higher tensile strength, higher speed and depth of cut favor obtaining smooth surfaces, assuming turning is performed with perfect tools. Yield point, elongation and reduction of area are less important for obtaining a smooth surface. Steel structure is of importance in so far as carbide layers in hyper-eutectoid steels tear the surface. The ferrite size in hypo-eutectoid steels has a smaller bearing on the surface condition. Austenitic steels can be smoothly machined with a relatively low speed in consequence of the hardening originating either from cold work or precipitation of martensite. Certain machining temperatures are necessary for a smooth surface. The necessity of using higher temperature to obtain smooth surfaces is probably due to the disappearing of the yield point at these temperatures. Cold work of work piece and chip decrease with increasing cutting speed. Besides the influence of the physical properties of the piece some mechanical causes, as for instance shape of tool, type and handling of machine tool used, are given as influencing the surface condition of a part machined. GN(12g)

Tool Steel Tests. *Engineer*, Vol. 149, May 2, 1930, page 498.

Briefly lists results of a series of tests made in works of Samuel Osborn and Co., Ltd., Sheffield to show capabilities of their tool steels. Steels used for tests were Double Musket and a special cutting alloy. Tests carried out include lathe tests, twist drill tests and milling cutter tests. LM(12g)

The Application of Tungsten Carbide to Circular Saws. G. M. Thompson. (Henry Disston & Sons.) *Mechanical Engineering*, Vol. 52, July 1930, pages 681–682.

The author briefly outlines the changes that have taken place in the design of circular saws and gives data on remarkable results recently achieved through the use of tungsten carbide tips brazed to the teeth at the cutting edge. GN(12g)

Drawing & Stamping (12h)

The Measurement of Initial Stresses in Hard-Drawn Tubes. James Fox. *Engineering*, Vol. 129, Jan. 17, 1930, pages 65–67.

Hollow sunk brass and arsenical copper tubes season crack provided sink is sufficiently large. Hollow sunk non-arsenical copper tubes do not season crack, although they may have high internal stress. Presence of stress is necessary for season cracking to occur. Season cracking is much greater when caused by initial internal stress. Major stresses may be either longitudinal or circumferential. LM(12h)

(i) Pickling

Pickling Solution for Stainless and Nickel Steel. W. E. Warner. *Machinery*, April 1930, Vol. 36, pages 626–627.

Proportions given are: 9 parts water, 1 part sulphuric acid, 1 part hydro chloric acid, and 1 part nitric acid. RHP (12i)

Protecting Iron During Acid Pickling. An Investigation of Cathodic Treatment. U. R. Evans & J. Stockdale. *Metals & Alloys*, Feb. 1930, Vol. 1, pages 377–378.

Pickling in acids is often employed as a means of removing oxide films from iron articles. To minimize an attack on the metal nitrogenous and colloidal substances such as quinolic coal tar bases, etc., are added to the bath. Making the articles cathodes to a current supplied from an outside source may also be practiced. Very thin (0.3 mm.) electrolytic sheet iron was treated in *N*/100 acid to remove oxide (temper color). Air was displaced by CO_2 and the acid was previously boiled free from oxygen. Bath was carefully replaced after 1 and again after 5 hours and each analyzed for soluble iron. Table is given showing soluble iron drawn off for *N*/100 and 10% sulphuric acid baths and cathodic current density. Another series of determinations was made replacing the bath at 15 minute intervals. The data are included. It is indicated that very low cathodic density enormously reduces corrosion. An explanation of the phenomenon is offered by the statement that the electric current deposits the metal nearly as fast as corrosion dissolves it and it, therefore, is only effective when the liquid layer to the metal becomes enriched in iron ions and impoverished in hydrogen ions. Metals may become resistant to acid by the formation of a layer of insoluble sulphuric acid, or by the establishment of a stage in which the potential *metal/metallic ions* is balanced by the potential *hydrogen/hydrogen ions*, in the case of iron this may be attained by the help of cathodic current. Again the formation of insoluble oxides may prevent corrosion and finally colloidal and nitrogenous substances are helpful. ESC(12i)

Cold Working (12j)

Metal for Brass Pickling Containers. P. D. Schenck. (Duriron Co.) *Iron Age*, Vol. 125, Mar. 27, 1930, page 917; *Iron Trade Rreview*, Vol. 86, Mar. 6, 1930, pages 87–88; *Heat Treating & Forging*, Vol. 16, Mar. 1930, pages 336–337.

Abstract of article read before the American Society of Mechanical Engineers in Buffalo. Considers importance of thorough testing of corrosion resisting metals under actual service conditions. Cites several concrete examples. VSP(12i)

Influence of Cold-Working on the Magnetic Properties of Steel. Benjamin S. Messkin. *Iron & Coal Trades Review*, Vol. 120, Feb. 28, 1930, page 373.

Brief abstract of a communication of the Institute for Metal Research in Leningrad. See *Metals & Alloys*, Vol. 1, Mar. 1930, page 430. RHP(12j)

Cold Heading and Thread Rolling. F. R. Daniels. *Iron Age*, Vol. 124, Oct. 17, 1929, pages 1027–1028.

Among the materials found to be specially well adapted for cold heading operations is a steel containing nickel 1–1.5, chromium 0.5, carbon 0.3–0.4%. VSP(12j)

Investigations of Cold-Worked Heavy Walled Tubes, the Changes in Properties. (Untersuchungen an kaltgereckten, dickwandigen Röhren unter besonderer Berücksichtigung der Veränderungen der Werkstoffeigenschaften.) H. Klein. *Mitteilungen Kaiser Wilhelm Institut für Eisenforschung*, 1929, Vol. 11, No. 20 (Report 138), pages 331–352.

Investigations on the state of stresses and the change of physical properties in expanding hollow cylinders were carried on with 5 materials, namely 2 plain carbon steels, 2 nickel-chrome and 1 nickel-tungsten steel. Results with hydraulically expanded tubes show that the newer theories of shear stresses, internal friction and deformation (in relation to changes in energy) can be applied for calculating coldwork. The increase of yield point corresponds to the degree of deformation. Inelastic deformations above 2% have their bearing on tensile strength, elongation and notch toughness. GN(12j)

Rolling Grooves in Aluminum Pistons for Airplane Engines. H. T. Lafflin. *Machinery*, April 1930, Vol. 36, page 611.

Describes a process of finishing aluminum pistons and rolling instead of cutting the grooves. RHP (12j)

(12l) Polishing & Grinding

Grinding Stainless Steel. W. E. Warner. *Machinery*, April 1930, Vol. 36, page 616.

Stainless steel dissipates heat slowly and is easily scorched by grinding. Wet grinding with a wheel having abrasive grains from No. 30–36 and a speed of 5000–550 feet/minute is most satisfactory. Longitudinal feed should be about 50 feet/minute and wheel feed should vary up to 0.004 inch. RHP (12l)

Grinding and Heat Treatment as Causes of Cracks in Hardened Steels, C. E. Sweetser. (Norton Co.) *Grits & Grinds*, Vol. 21, May 1930, pages 1–9.

Discussion of the influence of heat treatment and grinding on crack formation. (12l)

DEFECTS (13)

Pinholes in Cast Aluminium Alloys. N. F. Budgen. *Metal Industry* London, Sept. 27, 1929, Vol. 35, pages 293–296; Oct. 4, 1929, pages 319–322; *Industrial Chemist*, Vol. 6, Mar. 1930, pages 117–119.

Contains discussion. Slightly condensed from a paper presented to the Institute of Metals. Considers pinholes in the following series:

"Y" alloy (most pinholes)-4% Cu, 2% Ni, 1½% Mg.
"2L8" and "3L11" alloys-12 and 8% Cu.
"2L5" alloys-13% Zn, 3% Cu.
Al-Si alloy—9 to 14% Si.
Pure Aluminum.

Following are the factors which probably influence pinholes caused by evolution of gas at solidification. Quality of original Al ingot, melting and pouring temperature and time maintained molten, melting fuel and furnace. Rate of solidification. Turbulent pouring. Quality and quantity of alloying element present. Very slow cooling gives fewer blowholes. Ingots from fine spinnings and wire may cause pinholes. Pinholes can be eliminated by avoiding of high melting temperature, use of metal chills in sand molds or all metal molds, and use of very slow cooling to allow the escape of gas. Pinholes may be removed by the use of chlorine gases and boron trichloride. VSP (13)

Interstate Commerce Commission Reports on Rail Failures. H. W. Gillett. *Metals & Alloys*, Vol. 1, Feb. 1930, page 381.

A critical abstract. ESC(13)

Blowholes. Neville Deane. *Foundry Trade Journal*, Vol. 42, Jan. 9, 1930, page 31.

Blowholes are classified as follows: (1) Metal cast too cold, (2) metal cast too hot, (3) sand of the mold too damp, (4) sand rammed too hard and (5) blowholes due to cores. Another class of blowholes are due to the metal itself. Copper, silver, some gunmetals and various pure metals and alloys appear to occlude a gas when molten and give it out on solidifying. Such metals are remelted with a "scavenging" metal or alloy of the type to suit the defect involved. VSP(13)

CHEMICAL ANALYSIS (14)

Estimation of Copper and Nickel in Steel. W. L. Knoyle. Paper before Swansea Technical College Metallurgical Society, Feb. 22, 1930, 18 pages, price 1 s.

If small amounts of copper are associated with large amounts of iron, the separation is best effected by the precipitation of the copper as a sulphide by means of zinc sulphide in place of the usual ammonium sulphocarbonate. No new method is offered for the estimation of the nickel. (14)

The Spectrographic Determination of Cadmium, Lead and Iron in Zinc. D. M. Smith. *Transactions Faraday Society*, Vol. 26, March 1930, pages 101–118; Bulletin, British Non-Ferrous Metals Research Association, Mar. 1930, pages 7–14.

Report of an investigation carried out for the British Non-Ferrous Metals Research Association. Describes application of simple spectographic methods to determination of small quantities of impurities in Zn. Compares relative merits of arc and spark methods. Both methods are applicable but arc method is preferred on account of its greater sensitivity in the case of Pb. Method described is more rapid and affords greater accuracy than usual chemical methods of assaying. LM(14)

The Determination and Separation of Rare Metals from other Metals. XIX. New Methods for the Separation of Titanium from other Elements. (Die Bestimmung und Trennung seltener Metalle von anderen Metallen. XIX. Neue Methoden zur Trennung des Titans von anderen Elementen.) Ludwig Moser, Karl Neumayer & Karl Winter. *Monatshefte für Chemie und Verwandte Teile anderer Wissenschaften*, March 1930, Vol. 55, pages 85–97.

Three methods for the separation of Ti are described. (1) By hydrolysis with $KBrO_3$ in a solution of pH 7 hydrated TiO_2 precipitates free from adsorbed impurities, in contrast to TiO_2 precipitated in an alkaline solution. (2) Ti forms a soluble complex with sulpho-salicylic acid. This method has been previously described for the separation from Al and Fe. (3) When not more than 0.1 g. Ti is present, by precipitation with tannic acid. *A*. Separation of Ti from Cr: Method (1) Precipitate and ignite $TiO_2 + Cr_2O_3$, fuse with Na_2CO_3 and a little KNO_3. Dissolve in dilute HCl, neutralize with NaOH, using methyl orange. Then add 20 cc. 1: 10 HCl and let stand in the cold until the solution becomes clear. Add 1 g. K_2SO_4 and 1.5 g. $KBrO_3$ and boil. Hydrated TiO_2 precipitates. Filter, wash and ignite. In the filtrate reduce Cr^{IV} with alcohol to Cr^{III}, neutralize, add acetic acid and precipitate Cr with tannic acid. Method (2) obtain $TiO_2 + Cr_2O_3$ and fuse with $KHSO_4$. Dissolve in H_2SO_4. Add sulpho-salicylic acid and $(NH_4)_2CO_3$ or NH_4OH until the Cr in the solution turns gray, green or yellowish green and boil. Hydrated TiO_2 precipitates. Method (3) Neutralize the sulphate solution with NH_4OH, add 10 cc. conc. H_2SO_4, 40 cc. *N*/10 tannic acid and 20% anti-pyrin solution until orange-red precipitate forms. Filter, wash and ignite. *B*. Separation of Ti from Mn, Ni, Co and Zn. (1) Same separation as in A, but it cannot be used if Mn is present. Determine Ni in filtrate with dimethylglyoxime, Co as CoS or by electrolysis and Zn as $ZnNH_4PO_4$. (2) After same separation as in A, oxidize Mn with Br in NH_4OH solution, precipitate Mn_3O_4 and convert to $MnSO_4$ with $(NH_4)_2SO_4$. Determine Ni with dimethylglyoxime, Co as CoS or by electrolysis and Zn as ZnS. (3) Same separation as in A can be used. *C*. Separation from alkaline earths and Mg. Use method (1) Precipitate Ca as oxalate and determine as $CaSO_4$. Determine Ba as $BaSO_4$ and Mg as $Mg_2P_2O_7$. *D*. Separation from Be. Use method (1) Determine Be by double precipitation with NH_4OH. *E*. Separation from U. Use method (2) and determine U as $(NH_4)_2U_2O_7$, or method (3) and acidify filtrate with HNO_3, evaporate to dryness and precipitate U with NH_4OH. *F*. Separation from SiO_2. Use method (3). SiO_2 cannot be determined. *G*. Separation from H_3PO_4. Use method (3). Precipitate with tannin and antipyrin in normal H_2SO_4 solution. CEM(14)

Spectrographic Analysis of Alloys. (L'analisi spettrografica delle leghe metalliche.) G. Guzzoni. *La Metallurgia Italiana*, Feb. 1930, Vol. 22, pages 274–286.

Discussion of methods and apparatus used in spectrographic analysis. Qualitative analysis is briefly discussed. Most of the article deals with quantitative analysis by comparison of the position and intensity of the lines of the unknown with those of samples of known composition, especially in regard to determination of Mo and V in steel. The method is considered sufficiently exact for binary alloys, but not yet applicable with the necessary security and precision to ternary and more complex alloys. HWG(14)

The Reaction of Iodate and Tetravalent Vanadium in Alkaline Solutions. J. B. Ramsey & A. Robinson. *Journal American Chemical Society*, Vol. February, 1930, pages 480–483.

Iodate and tetravalent vanadium react completely in hot alkaline solutions. Phosphate catalyzes the reaction. The method of determining vanadium by means of this reaction is described. Results check on the average within 0.1% of the calculated if oxygen is excluded during the reaction. MEH(14)

A Method of Determining the Arsenic Content of Organic Arsenicals. F. E. Cislak & Cliff S. Hamilton. *Journal American Chemical Society*, Vol. Feb. 1930, pages 638–640.

The arsenic content of organic compounds can be determined readily and accurately by digesting the compound with hot sulphuric acid in the presence of potassium acid sulphate, diluting the solution thus obtained and titrating electrometrically with potassium bromate. MEH(14)

Determination of Mercury as Metal by Reduction with Hydrazine or Stannous Chloride. H. H. Willard & A. W. Boldyreff. *Journal American Chemical Society*, Vol. Feb. 1930, pages 569–574.

Conditions are given for the accurate gravimetric determination of mercury after reduction to metal by hydrazine in ammoniacal solution or by stannous chloride in HCl solution. In the latter method Fe, Cd, Bi, Cu, Pb, Sb, nitrate and sulphate do not interfere. There is always a definite constant loss due only to volatilization of Hg during filtration and drying, for which an accurate correction can be made. A rapid method of drying is described using acetone and dry air. MEH(14)

Ceric Sulfate as a Volumetric Oxidizing Agent. XIII. The Determination of Mercurous Mercury. H. H. Willard & Philena Young. *Journal American Chemical Society*, Vol. Feb. 1930, pages 557–559.

An accurate method is described for mercurous mercury, based upon its oxidation in hot sulphuric acid solution by excess ceric sulphate and titration of excess electrometrically with standard ferrous sulphate. Mercuric ion in large amount does not interfere. MEH(14)

A Note on the Detection and Estimation of Cobalt in Presence of Nickel. Abraham Lieberson. *Journal American Chemical Society*, Vol. Feb. 1930, pages 464–465.

The colorimetric method employed is the reduction by cobalt of arsenophosphotungstic acid in presence of cyanide whereby intensely blue tungstous acid is formed and the cobalt is oxidized to cobalticyanide. Under identical conditions nickel fails to reduce the complex tungstic acid reagent. The method provides for the detection of cobalt in the presence of 300–400 times its weight of nickel, and also for the rapid and accurate determination of 0.5 milligram of cobalt in presence of 10 times its weight of nickel. MEH(14)

The Analysis of Carbon in Iron and Iron Alloys. N. A. Ziegler. *Fuels & Furnaces*, Oct. 1929, Vol. 7, pages 1621–1622.

See *Metals & Alloys*, Feb. 1930, Vol. 1, page 388. (14)

The Application of Spectrographic Analysis in Iron and Steel Laboratories. K. Kellerman. *Metals & Alloys*, April 1930, Vol. 1, pages 480–483.

A translation. See also *Archiv für das Eisenhüttenwesen*, September 1929, pages 205–211. For abstract see *Metals & Alloys*, April 1930, page 477. ESC(14)

Determining Oxygen in Iron Alloys by Means of the Hydrogen-Reduction Method. (Ein Beitrag zur Frage der Sauerstoffbestimmung in Eisenlegierungen nach den Wasserstoffreduktions Verfahren.) H. Petersen. *Archiv für das Eisenhüttenwesen*, Jan. 1930, Vol 3, pages 459–472; *Stahl und Eisen*, Feb. 5, 1930, Vol. 50, pages 170–171.

CO must be determined by applying the hydrogen-reduction method for the analysis of oxygen in iron alloys. The synthesis of methane according to Sabatier and Sendersens was found to be suitable for the purpose. Hydrogen reduces CO to CH_4 and H_2O at 250° C. in presence of finely divided Ni mixed with 10% thoriumoxide. The method gave accurate results and was used for the oxygen analyses of iron alloys with carbon contents from 0.09–3.35%. It was found that even this improved hydrogen-reduction method does not give the same reliable results as the hot-extraction method. A bibliography of 178 references is given. GN(14)

The Iodine Sulphur Determination in Iron and Steel (Zur iodometrischen Schwefelbestimmung in Eisen und Stahl.) K. Gabiersch. *Stahl und Eisen*, April 3, 1930, Vol. 50, page 453.

Description of improvements for the determination of sulphur according to the iodine method as described by H. Holthaus, *Stahl und Eisen*, 1924, Vol. 44, pages 1514–1518. GN(14)

Contributions to Luminescence Analysis. (Beiträge zur Lumineszenanalyse.) Ernst Beutel & Artur Kutzelnigg. *Monatshefte für Chemie und Verwandte Teile anderer Wissenschaften.* March 1930, Vol. 55, pages 158–166.

Very small quantities of zinc compounds can be distinguished by their color when illuminated by ultraviolet light from an analytical quartz lamp. Metallic zinc and zinc sulphate, nitrate, oxalate, chromate, phosphate and chloride remain dark. Carbonate and silicate are green. ZnO is dark grey to greenish yellow or remains dark depending on its origin and treatment. Alkaline cyanide is light violet. Precipitated hydroxide, basic carbonate and ZnS are bluish white or grey. Colloidal solutions of Zn, ZnO, $Zn(CN)_2$ and ZnS have a faint color and are not characteristically luminescent. CEM(14)

A Study of the Various Methods for the Separation and Estimation of Nickel and Cobalt Salts. Frederick G. Germuth. *Chemist Analyst*, March 1930, Vol. 19, pages 4–10.

An accurate study of 4 methods led to the conclusions that the alpha benzildioxime method is most accurate for small quantities of Ni in presence of Co. The dimethylglyoxime method is best when Co is below 0.1 g. Interference of Cr in both methods is avoided by addition of cuprous ammonium chloride. For Co the KNO_2 method is too long for routine work. The nitroso-beta-naphthol method is suitable when less Co than Ni is present. Sn over 1.5% interferes by forming a compound with Co. CEM(14)

Determination of Small Amounts of Silver in Pyrolusite. Alfred Kundert. *Chemist Analyst*, Jan. 1930, Vol. 19, page 11.

Pyrolusite is insoluble in HNO_3. Decompose 100 g. ore by repeated additions of conc. HCl until a white residue is obtained. Neutralize with NH_4OH and pass H_2S into the cold solution. Filter and wash with 10% H_2SO_4. Ignite at low heat. Moisten residue with HNO_3, dilute and precipitate with HCl. Filter, dissolve in NH_4OH, acidify with HNO_3 and repeat until free from Pb. Finally electrolyze in CN solution or determine AgCl. CEM(14)

Notes on the Routine Analysis of Cast Irons and Iron Foundry Raw Materials. Arthur Smith. *Foundry Trade Journal*, Nov. 14, 1929, Vol. 41, pages 357–358, 360.

Carbon may exist in cast iron in several forms, the most notable being the graphite form. In molten cast iron carbon exists in solution as carbide of iron. In soft gray irons an all pearlitic matrix is associated with a combined carbon of from 0.85–0.89%. Some may contain as little as 0.65%. Difficulties in sampling. Outlines method of analysis. Estimation of total and graphitic carbon, also carbon in ferro-alloys. VSP (14)

Zirconium. V. Detection of Traces of Potassium in the Presence of Zirconium. Rufus D. Reed & James R. Withrow. *Journal American Chemical Society*, Nov. 1929, Vol. 51, pages 3238–3241.

Presented at the Columbus Meeting of the American Chemical Society, April, 1929. Zirconium can be removed by ammonium hydroxide and potassium detected in the filtrate by sodium cobaltic nitride, after eliminating the ammonium. The best and shortest way of eliminating zirconium prior to testing for potassium by sodium cobaltic nitrite is by throwing the zirconium into a complex ion with tartaric acid and controlling the acidity with sodium hydroxide and acetic acid. MEH (14)

Separation of Chromium from Dilute Chromic Acid Solutions. (Zur Theorie der Abscheidung des Chroms aus wässrigen Chromsaürelössungen (IV).) Erich Müller & O. Essin. *Zeitschrift für Elektrochemie und Angewandte Physikalische Chemie*, Jan. 1929, pages 2–10.

This paper is a continuation of the work published a short while ago by Stscherbakow (*Zeitschrift für Elektrochemie und Angewandte Physikalische Chemie*, 1929, Vol. 35, page 222). Tests show that on an ideally smooth electrode in pure chromic acid there is formed a molecular screen of basic chromic acid and chromic oxide by the smallest cathode polarization. The basic constituent of this screen adheres to the cathode and the acid to the anode. This screen retards the passage of the chromic acid into its pores and therewith its solution. With rising cathode polarization the hydrogen ion is more and more attracted into the pores of this screen by eléctrostatic action; and as long as this action is insufficient to attract the anion, no solution of the screen substance takes place. With larger sizes of anions this cathode tension must be proportionately greater. Even in purest chromic acid, as well as in mixtures with perchlorate or phosphate, when the hydrogen potential is insufficient, no solution of the screen takes place. Therefore, no reduction takes place of the chromic acid with hydrogen formation. For the smaller anions the cathode tensions, being smaller than the hydrogen potential, are sufficient to attract them through the screen and result in a reduction of the chromic acid. Actual electrodes have no ideally smooth surface, so that instead of a closed screen only a more or less perforated screen can exist, through which the $HCrO_4$ ions can pass more easily due to electrostatic tension. The greater the number of surface irregularities of the electrode, the greater the current passage, under reduction of the purest chromic acid, before formation of hydrogen sets in. This explains the absence of the current flow below the hydrogen formation point on a seemingly smooth electrode, as well as the difference in phenomena on smooth and platinized platinum and on carbon. Carbon distinguishes itself from platinized platinum, in that its surface shows many small and sharp irregularities causing it to act in the presence of H_2SO_4 as if it formed practically no screen before it. For this reason the electrolytic reduction on its surface is accomplished unhindered up to a considerable current strength, while on smooth platinum it is practically non-existent. This paper is illustrated with numerous charts. AJM (14)

Proof and Determination of Iron and Its Separation from Other Elements. (Nachweis und Bestimmung des Eisens und seine Trennung von anderen Elementen.) *Zeitschrift für analytische Chemie*, April 3, 1929, pages 75–79.

A new gravimetric method for the determination of iron by Fr. Zetsche & M. Nachmann is described which is based on the precipitation of iron by organic compounds of phosphoric acid. The exact method is given and its limitations discussed. Ha(14)

HISTORICAL AND BIOGRAPHICAL (15)

The History of Iron in America. Geo. W. Schulz. *Edgar Allen News*, Vol. 9, June 1930, pages 629–633.

A short sketch of the iron industry in America. MLM(15)

The Early Use of Metals. T. A. Rickard. *Journal Institute of Metals. Advance Copy* 525 (1930), 43 pages. *Engineer*, Vol. 149, Mar. 21, 1930, pages 319–320.

This paper comprises a world survey in brief compass of the use of metals in very early times. Most of the paper deals with the non-ferrous group. The author believes that the melting of copper preceded its extraction from minerals by some centuries and that the production of bronze began at a much later stage. Evidence is adduced to show that the first reduction of stone to metal took place about 3500 B.C. The author instances numbers of examples of the early uses of lead, copper, tin and zinc and draws deductions from the metal implements still extant. The paper includes a comprehensive bibliography and the author supports his views with a large amount of historical evidence. LM & AEH(15)

Nickel Coinage Grows in Favor. Crawford Wymon. (American Numismatic Society.) *Inco*, Vol. 9, No. 4 (1930), pages 13, 24–25.

Historical. (15)

Quicksilver—Past & Present. V. L. Eardley-Wilmot. *Canadian Mining Journal*, Vol. 51, June 6, 1930, pages 540–544.

Historical. WHB(15)

The Metallography of Some Ancient Egyptian Implements. H. C. Carpenter & J. M. Robertson. *Journal Iron & Steel Institute*, May 1930, *Advance Copy* 6, 32 pages.

The authors have made an examination of various metal specimens of the Egyptian period and have examined their inner crystal structure and what they term their "micro-hardness." They state that the Egyptian process of extracting iron was very primitive, and great differences in carbon contents are noticeable. Carburization and heat treatment were understood as nine specimens had been so treated. Some specimens examined had been quenched and one had been tempered. They conclude that the art of heat treatment advanced during the period 1200 B.C. to A.D. 200. The authors conclude that the Iron Age in Egypt only began after the technique of carburizing and heat treatment had been discovered. AEH(15)

The History of the Cementation Process of Steel Manufacture. Part I. David Brownlie. *Journal Iron & Steel Institute*, May 1930, *Advance Copy* 5, 19 pages.

This paper gives the results of a search at the Record Office, London, among state and domestic papers, made to ascertain whether the contention that Ellyott and Meysey originated the cementation process in England is correct. The author finds the process was known on the Continent of Europe before their time but is unable to find evidence as to which country was the originator of the process. AEH(15)

The Historical Origin of the Open Hearth Process. (Zur geschichtlichen Entstehung des Herdofenverfahrens.) E. Maurer & W. Bischof. *Stahl und Eisen*, April 19, 1930, Vol. 50, pages 477–484.

After an outline of the steel processes before the development of the Siemens-Martin process, the development of the open hearth process by Siemens and Martin is considered in detail. Contrary to general opinion it is proved that the regenerative principle was invented by Robert Sterling in 1816. The merit of Siemens is to have introduced the regenerative heating system for hearth melting furnaces in the glass industry, whereas Pierre Martin in 1865 developed by means of the Siemens furnace the pig-iron-scrap steel process. GN(15)

Fifty Years of Grooved Rails (50 Jahre Rillenschienen). *Stahl und Eisen*, March 27, 1930, Vol. 50, pages 397–399.

Abstract of the book "50 Jahre Rillenschienen," published by *Zentralwerbestelle Dortmund der Vereinigten Stahlwerke A.G.* The historical development, the metallurgical improvements and the improvements in the process in manufacturing street car rails are outlined. GN(15)

German Version of Birth of Stainless Steel. Phil. H. Schottky. *Iron Age*, Dec. 5, 1929, Vol. 124, page 1512.

Discusses the development of corrosion resisting steels at the Krupp works. Corrosion problems have been investigated by Krupps since 1909. Deals with the properties and working of the alloy steel known as V2A steel. VSP (15)

Steel Founders Contribution to the Railroads. *The Commonwealther*, April 1930, Vol. 16, pages 19–23.

Extracts from an address by W. M. Sheehan before the New York Railroad Club. Shows the rapid advance in the use of cast steel in railroad work, from the days of wooden coaches up to the present time. MLM (15)

Historical Notes on Chains and Chain-making. P. Jump. *Proceedings Staffordshire Iron & Steel Institute*, Session 1928–29. Vol. 44, pages 1–18.

Gives general remarks about the chain trade of South Staffordshire and East Worcestershire including a few export and import figures for the entire United Kingdom. Includes historical notes arranged chronologically from 1044 B. C. to 1909. Numerous foot-note references are given. LFM (15)

The Purity of Lead at the Time of Christ. (Ueber Bleireinheit zur Zeit um Christi Geburt.) August Ebeling & Hans Adam. *Wissentschaftliche Veröffentlichungen aus dem Siemens-Konzern*, Vol. 8, part 3, 1930, pages 203–210.

A piece of Pompeian water pipe was examined and analyzed. It contained many small cracks filled with lead oxide, which were probably due to recrystallization after mechanical working. No trace of solder was found. The lead analyzed: Sn 0.451, Cu 0.066, Sb 0.075, As 0.006, Ag 0.004, Fe 0.005, Zn 0.003, Si 0.004. The interior was covered with lead carbonate. Photographs and a photomicrograph are given. A piece of a lead coffin from the early Christian period found on the Dalmatian coast analyzed 99.8% Pb, 0.119% Sn. Includes bibliography of technical and historical articles. CEM (15)

The Early History of Stainless Steel. P. R. Kuehnrich. *Foundry Trade Journal*, Sept. 12, 1929, Vol. 41, pages 185–186; see also editorial Sept. 26, 1929, page 219.

Translated from Soligen Tageblatt. Traces the development of rustless chromium steels including their utilization for the manufacture of cutleries. Treats briefly of P.R.K. patent cutlery steel. VSP (15)

ECONOMIC (16)

The Spanish Iron and Steel Industry. Luis Barreiro. *Iron & Coal Trades Review*, Vol. 120, Jan. 24, 1930, page 163–164.

Review of the industry for 1929. RHP(16)

World Iron and Steel Industry. William Larke. *Iron & Coal Trades Review*, Vol 120, Jan. 24, 1930, pages 151–152.

Brief résumé of the industry in 1929 for countries excepting Great Britain. RHP(16)

Stability of Nickel Industry. E. D. Loney. *Canadian Mining Journal*, Vol. 51, June 6, 1930, pages 545–546.

A brief review of the activities of the International Nickel Co. of Canada, Limited. WHB(16)

Steel Foundry Budgetary Control. A. K. Reading. (Zimmerman Steel Co.) *Paper read before the Steel Founders' Society*, May 14, 1930, Cleveland, Ohio.

The author points out the benefits obtained by the preparation of a budget. With the cost summary of the Steel Founders' Society as a guide the author's company set up a budget in 1928. With the budget functioning, various improvements in practice and equipment were found necessary, and decided improvements accomplished. In conclusion the author points out that many phases of shop operation show up in a much more important manner than they do if budgeting is not attempted; while others, which generally have been thought of as highly influential on costs, scarcely warrant the excessive attention that has been paid to them. The percentages of total cost found in this shop were: metals 16.75; conversion 16.65; direct labor 12.08; molding indirect expense 10.5; core indirect expense 2.28; cleaning indirect expense 10.66; annealing indirect expense 2.45; sand indirect expense 1.70; core mixtures 0.9%. (16)

Canadian Iron and Steel Industry. *Iron & Coal Trades Review*, Vol. 120, Jan. 17, 1930, page 79.

Brief review of some of the current events in the iron and steel industry of Canada, including new plants, new steel tariff and other economic factors. RHP(16)

World Reserves and Resources of Tin. Charles White Merrill. *United States Bureau of Mines Information Circular* 6249, March 1930, 8 pages.

The United States consumes over 40% of the world's virgin tin production. Domestic production is negligible. Total published reserves (from companies responsible for 25% of production) are as follows (long tons): Producers—placers—366,795, lodes—141,006; Non producers—placers—237,933, lodes—15,050. Federated Malay States account for over 60% of these reserves; Nigeria is second and Siam third. A tin famine is not imminent due to (1) the flood of new capital which entered the field during the recent years of high prices, (2) all the important alluvial tin areas are increasing their output, (3) Bolivia, the greatest lode producer, is increasing its production, (4) other lode producers are holding their own, (5) protection of the major tin producing areas from excessive exploration due to their inaccessibility and (6) many of the uses for tin are not destructive. AHE (16)

Russia's Steel Industry. King Hamilton Grayson. *Mining & Metallurgy*, Dec. 1929, Vol. 10, pages 565–566.

Iron and steel in 1928 lagged behind the prewar production, due to complete obliteration of industrial units during the revolution. The 1921 production being only 4% of that of 1913. By 1927 it reached a point equal to 70.5% of 1913 of pig iron, steel was 84% and rolled iron 78%. High grade steel, rust proof iron and steel and additional lines of steel products were started during 1928. This is being done at Byedovetsk in the Urals. Iron ore production for 1913 cannot be equalled for several years. Krivori-Rog mines have been furnishing 70% of the iron ore, and the Urals 27%. Iron ore deposits are still comparatively undeveloped. The requirements for iron and steel during the next 5 years in the Soviet republic is estimated at 27,000,000 tons. At the most, only 80% of this can be produced in Soviet mills. The magnet mountain metallurgical plant in the Ural mountains is under construction. Krovoi-Rog works will be completed in 1933, having an annual output of 660,000 metric tons of pig iron and 260,000 metric tons of rolled iron. Other plants under construction are: The Telbes in Kuznetsk basin, Kerch-Crimean and at Dnieper, Providence, Makeevka and Kadiev. Yugostal Steel Trust is the largest producer at the present time. VSP (16)

The Future of Zinc in Brass. William A. Willis. *American Metal Market*, April 17, 1930, Vol. 37, No. 75, pages 5, 10.

A paper presented at the Annual Meeting of American Zinc Institute at St. Louis, Mo., April 15, 1930. The outlook for zinc in brass-making is decidedly encouraging. Zinc's problem appears to be one of underconsumption rather than one of overproduction. WHB (16)

Gold, Silver, Copper, Lead and Zinc in the Eastern States in 1927. J. P. Dunlop. *Mineral Resources of the United States*, 1927—Part 1, *United States Bureau of Mines*, 1928, pages 1–6.

The total value of gold, silver, copper, lead and zinc production in the Eastern States in 1927 was $20,127,366, an increase of less than 1% over 1926. The quantity of copper, zinc and gold increased and of silver and lead decreased. The decrease in silver recovery was 21% in quantity and 28% in value. AHE (16)

Gold, Silver, Copper and Lead in Oregon in 1928. V. C. Heikes. *Mineral Resources of the United States*, 1928—Part 1, *United States Bureau of Mines*, 1930, pages 311–320.

The total value of gold, silver, copper and lead in Oregon in 1928 was $296,446, a decrease of 25% from 1927. The value of the gold decreased 26%, silver 30% and copper 19%; the value of lead increased 130%. AHE (16)

British Steel-Makers and the Canadian Market. *Iron & Coal Trades Review*, Vol. 120, Jan. 31, 1930, pages 208–209.

Canada imports 300,000 tons of steel annually. A large part of this is from the United States. Discusses the effect of the United States tariff on the situation as regards return buying and possible advantage which the British steel industry might make of this. Gives statistics regarding the import of several metal products and the countries from which they are imported. RHP(16)

The German Iron and Steel Industry. J. W. Reichert. *Iron & Coal Trades Review*, Vol. 120, Jan. 24, 1930, pages 160–161.

Review of the industry for 1929. RHP(16)

The World's Reserves of Tin. *Engineer*, Vol. 149, May 2, 1930, page 493.

From recent report of the United States Bureau of Mines. Over 40% of world's production of tin is consumed in the U. S. and 99% of that used is imported from foreign sources. Gives production figures for various countries. LM(16)

Iron and Steel Industries in 1930. *Engineer*, Vol. 149, Jan. 24, 1930, page 113.

Gives British production figures reported by National Federation of Iron and Steel Manufacturers. Includes table showing average monthly production of pig-iron and steel ingots and castings in 1913, 1920 and 1926 to 1929, and the production for each month since December 1928. Total figures for 1929 show 7,579,500 tons of pig-iron produced, and 9,654,700 tons of steel ingots and castings compared with 6,610,100 tons and 8,519,700 tons respectively in 1928. LM(16)

The Iron and Steel Trade. History and Prospects. *Iron & Coal Trades Review*, Vol. 120, Jan. 17, 1930, page 85.

The article deals largely with the economic phase of the present status of iron and steel with brief reference to some past occurrences in the industry. RHP(16)

District Reviews of the Iron and Steel Industry. *Iron & Coal Trades Review*, Vol. 120, Jan. 24, 1930, pages 143–151.

General review of the industry for 1929 in the following districts: North of England, Scotland, Sheffield and District, North-West of England, South Staffordshire, South Wales and Lancashire. RHP(16)

Diagrams of Three Months' Fluctuations in the Prices of Metals. *Engineering*, Vol. 129, June 6, 1930, page 744.

Compiled from official reports of London metal markets for March, April and May 1930. LM(16)

The Steel Sheet Trade. *Iron & Coal Trades Review*, Vol. 120, Jan. 24, 1930, pages 155–156.

Discusses the production, exports, imports and general trade tendencies of the steel sheet industry in 1929. Includes comparative figures for several preceding years. RHP(16)

United States Steel Industry in 1929. *Iron & Coal Trades Review*, Vol. 120, Jan. 24, 1930, page 159.

Brief summary of general conditions and production. RHP(16)

Gold, Silver, Copper, and Lead in South Dakota in 1927. Chas. W. Henderson. *Mineral Resources of the United States*, 1927—Part 1, *United States Bureau of Mines*, 1929, pages 301–306.

The value of gold, silver, copper and lead in South Dakota in 1927 was $6,720,210, an increase over 1926 of about 15%. This output is almost entirely gold, of which the major production came from the Homestake mine, the largest gold mine in the United States, which has been producing almost continuously since 1875. AHE (16)

Gold, Silver, and Copper in Wyoming in 1927. Chas. W. Henderson. *Mineral Resources of the United States*, 1927—Part 1, *United States Bureau of Mines*, 1929, pages 307–308.

Wyoming non-ferrous deposits were productive in 1927 for the first time since 1923. Production amounted to $1200 worth of gold and 5 ounces of silver, worth $3. AHE (16)

Gold, Silver, Copper, Lead and Zinc in California in 1928. V. C. Heikes. *Mineral Resources of the United States*, 1928—Part 1, *United States Bureau of Mines*, 1930, pages 285–309.

The total value of gold, silver, copper and lead in California in 1928 decreased 9% from 1927 to $15,381,783. The production of gold declined 8%. Silver output was 9% less in quantity and 6% in value. Production of copper decreased 7% in quantity and increased 2% in value. Output of lead decreased 30% in quantity and 36% in value. No zinc was reported produced in 1928. AHE (16)

Gold, Silver, Copper, Lead and Zinc in New Mexico in 1927. Chas. W. Henderson. *Mineral Resources of the United States*, 1927—Part 1, *United States Bureau of Mines*, 1929, pages 455–476.

Gross values of gold, silver, copper, lead and zinc in New Mexico in 1927 increased 8% over 1926 to a value of $15,662,076. This production came from 102 lode mines and 10 placers, a decrease of 14 lode mines and 2 placers. Gold production increased nearly 50%, silver output nearly doubled, copper production decreased 10%, lead increased 130% and zinc increased almost 150%. The source of this output by types of ore and localities is discussed. AHE (16)

Silver, Copper, Lead and Zinc in the Central States in 1928. J. P. Dunlop and H. M. Meyer. *Mineral Resources of the United States*, 1928—Part 1, *United States Bureau of Mines*, 1930, pages 169–203.

The total value of mine production of silver, copper, lead and zinc in the states of Arkansas, Illinois, Kansas, Kentucky, Michigan, Missouri, Oklahoma and Wisconsin in 1928 was $95,665,149, a decrease of almost 10% from 1927. Production of silver, lead and zinc decreased; copper (nearly all from Michigan) increase. Figures are also given by states and districts. AHE (16)

Electrotechnical and Electrometallurgical Industries in the Pyrenees. (Les industries electrotechniques et electrometallurgiques dans les Pyrenees.) R. Sevin. *Journal du Four Electrique*, Feb. 1930, Vol. 39, pages 49–52.

A description of Lannemezan plant of Société des produits Azotes. JDG (16)

Reports Show How Railroads Lead in Steel Consumption. *Iron Trade Review*, Jan. 9, 1930, Vol. 86, pages 21–23.

Presents an analysis of automotive and railroad consumption in the United States as indicated by returns from 106 steel producers. MS (16)

Rising Tide of Alloy Steels Finds Producers Eager for Action. J. D. Knox. *Iron Trade Review*, Jan. 2, 1930, Vol. 86, pages 14–18.

Discusses distribution of alloy steels and the attention that will be given by manufacturers to marketing and production problems. Useful for the list of trade names of alloy steels and their producers. MS (16)

United States Leads World in Per Capita Steel Consumption. *Iron Trade Review*, Jan. 30, 1930, Vol. 86, pages 11–13.

Steel output per capita in the United States for 1929 was more than 100 lb. per person. This is more than twice that of Germany and three times that of France. Tables show pig-iron and steel output in United States for each year from 1878–1929. MS (16)

World's Aluminum Industry. (L'Industrie mondial de l'aluminium.) R. J. Anderson. *Journal du Four Electrique*, Feb. 1930, Vol. 39, pages 54–55.

A brief review of aluminum industry of the world in 1929. JDG (16)

Commercial Application of Beryllium. *Engineering & Mining Journal*, Dec. 21, 1929, Vol. 128, page 963.

The metal could be manufactured at much lower costs than now prevail with the market absorbing appreciable tonnages annually. WHB (16)

Railroads Regain Lead in Steel Consumption. *Iron Trade Review*, Jan. 2, 1930, Vol. 86, pages 36–39.

Statistics on the consumption and distribution of steel products. MS (16)

Gold, Silver, Copper, Lead and Zinc in Nevada in 1927. C. N. Gerry. *Mineral Resources of the United States*, 1927—Part 1, *United States Bureau of Mines*, 1929, pages 509–525.

The value of mine production of gold, silver, copper, lead and zinc in Nevada in 1927 was 5% less than in 1926. Copper output was the only one to increase (18% in quantity, 10.5% in value). The largest decrease in value was silver (25%), due to the smallest production recorded since 1904. Gold production was the smallest since 1903. Lead production decreased 29% and zinc 41%. AHE (16)

Gold, Silver, Copper, Lead and Zinc in Colorado in 1927. Chas. W. Henderson. *Mineral Resources of the United States*, 1927—Part I, *United States Bureau of Mines*, 1929, pages 527–572.

The value of recovered and estimated recoverable gold, silver, copper, lead and zinc in Colorado in 1927 decreased 19% from 1926 to $16,965,162. There were appreciable increases in quantity for copper (67%) and zinc (10%) but decreases for the others. There were 330 lode mines and 19 placers producing in 1927, a decrease of 57 lode mines and 12 placers. A review by counties is given. AHE (16)

Here Today, Gone Tomorrow, Elusive Markets Lead Steelmakers in Merry Chase. G. H. Manlove and W. H. Lloyd. *Iron Trade Review*, Jan. 2, 1930, Vol. 86, pages 7–10.

Discusses shifts in the consumption of steel products. In the oil industry, autogenous electric welded pipe is replacing seamless tubing for line pipe. Seamless tubing has supplanted welded tubes for deep well drilling. Cr-Ni steels are being used in high pressure and temperature cracking stills. In the building industry, steel frame houses are gaining favor, and steel is replacing wood for many purposes. Automobile industry is turning to wide strip steel. MS (16)

Belgian Iron and Steel Industry in 1929. *Iron & Coal Trades Review*, Vol. 120, Jan. 24, 1930, pages 162–163.

Review of the year. F. O. B. steel prices fell during the year while production costs rose. RHP(16)

French Iron and Steel Industry in 1929. *Iron & Coal Trades Review,* Vol. 120, Jan. 24, 1930, pages 161–162.

Review of the industry. 1929 was not as prosperous a year as 1928. RHP(16)

British Imports and Exports of Iron, Steel and Other Metals in 1929 *Iron & Coal Trades Review,* Vol. 120, Jan. 17, 1930, pages 91–93.

Summarized tables showing the comparative figures for 1928–1929. Includes machinery and hardware. RHP(16)

Manganese Situation in the United States in 1929. *Iron & Coal Trades Review,* Vol. 120, Feb. 21, 1930, page 336.

Abstract of the preliminary report of the U. S. Bureau of Mines. Their report shows an increase of about 30% in deliveries of manganese ore containing 35% or more of metallic manganese which totals about 61,000 long tons. This increase was mainly due to the increased output of Domestic Manganese & Development Company at Butte, Montana. Imports of the U. S. for 1929 are shown by figures of the U. S. Bureau of Foreign and Domestic Commerce. RHP(16)

Iron and Steel Production. *Iron & Coal Trades Review,* Vol. 120, Feb. 7, 1930, page 249.

Figures compiled by the National Federation of Iron and Steel Manufacturers. Gives British production of pig-iron and steel by districts for 1913, 1928–1929. RHP(16)

World's Output of Pig-Iron and Steel in 1928. *Iron & Coal Trades Review,* Vol. 120, Feb. 7, 1930, page 250.

Tables showing the world's estimated output in 1928 of pig-iron, ferroalloys, steel ingots and castings are reproduced from the Statistical Summary 1926–1928 issued by the Imperial Institute relating to the "Mineral Industry of the British Empire and Foreign Countries." RHP(16)

Swedish Iron and Steel Industry in 1928. *Iron & Coal Trades Review,* Vol. 120, Feb. 7, 1930, page 241.

Review of the industry giving total production, production of various products, fuel used and the number of plants and furnaces operating. RHP(16)

British Imports and Exports of Iron and Steel in 1929. M. S. Birkett. *Iron & Coal Trades Review,* Vol. 120, Jan. 24, 1930, pages 153–154.

Includes figures for 1913, 1928 and 1929 showing the products imported and exported with the export destinations. RHP(16)

The Tinplate Trade in 1929. J. D. D. Davis. *Iron & Coal Trades Review,* Vol. 120, Jan. 24, 1930, page 157.

Statistics of production and export of tinplate. General review of the industry. RHP(16)

Review of the British Iron and Steel Industry in 1929. E. J. Fox. *Iron & Coal Trades Review,* Vol. 120, Jan. 24, 1930, pages 142–143.

Total tonnage for the year was 9,654,700 tons of steel. The pig-iron produced was 7,579,500 tons. Contains table showing number of furnaces in blast during each month, price index, production, export and imports, and stock quotations for a few stocks. General discussion of the industry RHP(16)

The World's Vanadium Resources. (Världens Vanadinmalnistilganger.) Harald Carlborg. *Jernkontorets Annaler,* Vol. 114, Feb. 15, 1930, pages 52–75.

General summary. Discusses the forms of vanadium minerals, the uses of vanadium, the price of vanadium since 1922, the geographical distribution, production statistics and future developments. It is concluded that the present world production of about 1000 metric tons per annum can be maintained for several decenniums without resorting to low-grade ores. HCD(16)

German Steel and the World Market. *Iron & Coal Trades Review,* Vol. 120, Mar. 7, 1930, page 420.

Abstract from the Krupp'sche Monatshefte. Germany lost most of her ore supply when she lost the Lorraine at the end of the World War. A table of the output and exports of steel for Germany, France, Belgium-Luxemburg, Great Britain and the United States for the years 1913 and 1928 is given. The output of steel in Germany declined from 18,935,000 tons in 1913, to 14,517,000 tons in 1928. Exports from Germany have decreased whereas the other countries mentioned have either had a very small decrease or large increase. RHP(16)

Statistical Compilations on Lead, Copper, Zinc, Tin and Aluminum. *Metallgesellschaft,* May 1930, pages 24–33.

Gives the production, prices and foreign trade for the above metals. MLM(16)

The Case for Bessemer Steel. *Engineering,* Vol. 129, March 28, 1930, pages 413–414.

Editorial commenting on fact that British manufacturers are making so little steel by Bessemer process. In 1928 only 5.6% of the steel manufactured was made in acid converter. Since 1926 no steel has been made by basic Bessemer process. Enumerates objections which have been made to steel manufactured by basic Bessemer process. States that many tons of steel produced by this method are annually imported from Continent. By proper organization much of this trade would revert to home manufacturers. LM(16)

PLANTS & LABORATORIES (17)

The Experiment Station in the New Laboratory for Physics, Chemistry and Electrochemistry at the Technische Hochschule Stuttgart. (Die Experimentieranlage im neuen Laboratorium für Physik, Chemie und Elektrochemie der Technischen Hochschule Stuttgart.) W. Jackel. *Siemens Zeitschrift,* Vol. 10, Feb. 1930, pages 102–107.

Illustrated description of the new experiment station installed by Siemens & Halske in the Technische Hochschule Stuttgart, Germany. GN(17)

Condition of Material Watched Closely in Ball Bearing Manufacture. *Iron Age,* Vol. 125, Mar. 6, 1930, pages 703–706.

Describes procedure at the Hartford plant of the S.K.F. Industries, Inc. Races for bearings up to 6 in. are made from steel similar to S.A.E. 52,100, having 0.95–1.05% carbon, 1.40–1.65% chromium and 0.25–0.40% manganese, with sulphur 0.020 and phosphorus 0.025%. A sample of every heat of steel received is tested chemically. Until approved by the laboratory the steel is not admitted to the manufacturing department. First race manufacturing unit is the lathe department. Hardening room is equipped with three gas-fired continuous furnaces with automatic temperature and mechanical control. Quenching oil temperature is held automatically to about 110° F. After hardening, washing and sand blasting the parts are tested, and finally ground. VSP(17)

The New Plant of the Mannesmann Tube Works, Division Schulz Knaudt at Huckingen. (Die Neuanlagen der Mannesmannrohren-Werke, Abteilung Schulz Knaudt in Huckingen.) A. Michel and P. Stern. *Stahl und Eisen,* Vol. 50, May 29, 1930, pages 753–761; *Iron & Coal Trade Review,* Vol. 121, July 11, 1930, pages 35–39.

Report No. 113 of the Blast Furnace Committee of the Verein deutscher Eisenhüttenleute. The authors describe the blast furnace and power plant of the new steel mill of the Mannesmann Tube Works at Huckingen. GN(17)

The New Physical Institute of the Technical Hochschule Danzig. (Das neue physikalische Institut der Technischen Hochschule Danzig.) F. Wolf. *Siemens Zeitschrift,* Jan. 1930, Vol. 10, pages 22–29.

Detailed description of this new institute. GN(17)

How the Siemens-Schuckert Works Test Materials. (Von der Werkstoffprüfung bei den Siemens-Schuckert Werken.) *Siemens Zeitschrift,* Dec. 1929, Vol. 9, pages 878–880.

Equipment of the testing laboratories of the Siemens Schuckert works are described and illustrated. GN(17)

Steel Corporation Research Program. John Johnston. *Iron Age,* Jan. 2, 1930, Vol. 125, pages 61–62.

In the laboratory at Kearney only fundamental investigations are taken up and as work on a larger scale is desirable it is transferred to another laboratory. Other research laboratories are located at Pittsburgh and South Chicago. Fundamental work on the behavior of iron at high temperature is being investigated. Describes the laboratory building and equipment at Kearney. VSP (17)

Airplane Tie Rods and Tie Rod Wire. C. B. Phillips. *Heat Treating & Forging,* Jan. 1930, Vol. 16, pages 103–104, 107. *Iron Trade Review,* Jan. 1930, Vol. 86, pages 47–50.

Descriptions of operations at the Macwhyte Co., Kenosha, Wis. for the manufacture of streamline tie rod. Raw material is pickled in H_2SO_4 for 3–5 min. at 140° F., washed, dipped in cold $CuSO_4$, and placed in lime bath at 180° F. The coils are baked at 300° F. for 6 hours in gas-fired ovens to drive off absorbed H_2. Raw material is patented as well as is the wire at different stages in the drawing process, number of treatments varying from one to three. Patenting furnaces and blocks are designed to give continuous and automatic operation. Furnaces are gas-fired, and permit the maintenance of any desired atmosphere. Temperature in heating chamber is 1750–1800°F. Temperature gradient through the critical range of the grade and weight of steel being treated is controlled by varying the speed at which it is pulled through. Sorbitic structure is obtained. Heating periods range from $1^1/_4$–5 min. Gas consumption is 3200 cu. ft. of manufactured gas per ton of wire. Scale loss is 1%. MS (17)

The Pipe Works of the South Durham Steel and Iron Company, Limited. *Iron & Coal Trades Review,* Jan. 3, 1930, Vol. 120, pages 1–2.

Describes the manufacture of lapwelded steel pipe as it is carried out in the plants of this company. All pipes after welding are tested in a hydraulic testing machine, lined and treated with a bituminous solution. The annealing furnaces, tube heating stoves, dipping tanks and the portable oil-fired plate heating furnaces are discussed. RHP (17)

Galvanizing Works of Messrs. Baldwins, Limited, at Hereford. *Iron and Coal Trades Review,* Jan. 10, 1930, Vol. 120, page 47.

Describes the installation in this plant which is capable of handling 200 tons of material per week. RHP (17)

Makes Textile Machinery Castings in a New Foundry. Pat Dwyer. *Foundry,* Jan. 1, 1930, Vol. 58, pages 88–93, 103.

Describes foundry of the Textile Machine Works, Berkshire Knitting Mills and the Narrow Fabric Co., comprising the Wyomissing industries. VSP (17)

MACHINERY & SUPPLIES (18)

Some Notes on Cupola Receivers. M. G. Woods. *Foundry Trade Journal,* Nov. 14, 1929, Vol. 41, pages 353–354, 356.

Several types of cupola receivers have been introduced, such as the iron and slag separating device, jolting receiver, receivers heated by external means, etc. Describes each receiver. Advantages of receivers. The value of a receiver depends on the class of castings being made. Where light, small intricately-cored castings are produced, there are no advantages in using receivers. Metal should be taken straight from the cupola. A receiver is of great advantage when charge consists of pig iron, cast iron, shop returns and steel scrap. VSP (18)

Equipment for Building Aircraft Engines. Charles O. Herb. *Machinery,* Mar. 1930, Vol. 36, pages 505–510.

Illustrations and description of the tools, methods and some of the materials used in the shop of the Continental Motors Corporation in the manufacture of air-cooled radial type engines. RHP (18)

BIBLIOGRAPHIES (19)

Review of Iron and Steel Literature for 1929. E. H. McClelland. *Blast Furnace and Steel Plant,* Jan. 1930, Vol. 18, pages 122–123; Feb. 1930, pages 309–312.

An annotated, classified list of the more important books, serials and trade publications issued during the year, with a few of earlier date, not previously announced. MS (19)

MISCELLANEOUS (20)

Studies in Contact Rectification. I. Classification of Contact Rectifiers. Milton Bergstein. (P. R. Mallory & Co.) *Preprint* 57–19, *American Electrochemical Society Meeting,* May 29–31, 1930, pages 205–212.

Preliminary to a general study of contact rectification, the known contact rectifiers are classified according to a mechanical structure and the chemical nature of the more electronegative member. In contact rectifiers current flows generally from the more electronegative member to the more electropositive, but at lower a.c. voltages (as is indicated for CuS-Mg) the current flow may be in the reverse direction. An adequate theory of contact rectification must explain both these phenomena. (20)

Utilization of Blast Furnace Slag. Fred Clements. *Edgar Allen News,* Vol. 9, June 1930, page 635.

A short excerpt from "Blast Furnace Practice" by Clements. MLM(20)

Gold from Antimony Ores. *Engineer,* Vol. 149, March 7, 1930, page 279.

From "Mining and Industrial Magazine," a South African publication. Discusses briefly process used by J. R. Williams for recovering gold content of the antimonial ores of the Murchison Range. LM(20)

The Heating of Ladles. *Iron & Coal Trades Review,* Vol. 120, Mar. 14, 1930, page 455.

Summary of a report by the Steel Works Committee to the Association of German Iron Masters. Discusses the construction and life of ladles and various ways of heating them. RHP(20)

A Model to Explain the Mechanism of Electrolysis. M. DeKay Thompson. (Massachusetts Institute of Technology.) *Preprint* 57–9, *American Electrochemical Society,* May 29–31, 1930, pages 81–84.

A model is described which illustrates the mechanism of electrolysis showing the following: (1) that there is no change in the middle portion; (2) that the solution remains electrically neutral at the electrodes; (3) that the loss at the anode is proportional to the velocity of the cation, and the loss at the cathode is proportional to the velocity of the anion. This is done for three different relative velocities of anions and cations. (20)

Sparks from Metals Generated by Grinding. H. W. Wagner. (Norton Co.) *Grits & Grinds,* March 1930, pages 1–9.

Describes character of sparks from certain metals and gives suggestions for practical application. Includes a table of kinds of sparks from various metals. MLM(20)

Photographic Action from Metals, Woods, Etc. J. G. Strachan. *Journal Royal Technical College*, Vol. 2, Jan. 1929, pages 20–29.

Experiments are described showing the photographic effect produced in the dark by certain metals, woods and liquids. (20)

Failure of a 48-Inch Cast Iron Main Under Earth Pressure. Wm. W. Bush. (Chief Engineer of Water Supply, New York City.) *Journal American Water Works Association*, Vol. 22, June 1930, pages 753–754.

The failures briefly described here were fully described in the Engineering News-Record of August 25, 1927. The author makes the point that in designing a pipe line it is necessary to figure the load as the total weight of earth above it, as the usual assumption of the formation of an arch over the pipe which takes up a certain amount of the load does not work out in practice. An examination of 2000 feet of 48" main laid in 1891 and of 3500 feet of a double line of 48" main laid in 1895 with a wall thickness of 1" showed 59 cracked lengths in 2000 feet and 32 cracked lengths in 3400 feet. The cracks were old ones and came generally in the sections lying under street crossings with cover up to 28 feet. Some of the pipes were cracked top and bottom, a few on the sides and more on the top or bottom only. *Abstract Bulletin National Tube Company.* (20)

Some Reactions of Nickel Carbide, Ni_3C, prepared at low Temperature. (Einige Reactionen des bei niedriger Temperatur hergestellten Nickelcarbides Ni_3C.) H. A. Bahr & Th. Bahr. *Berichte Deutschen Chemischen Gesellschaft*, Vol. 63, Jan. 1930, pages 99–102.

Ni_3C was prepared at low temperatures and its reactions with all common reagents are described. CEM(20)

The Effect of Unequal Speeds of Rotation in Crushing Rolls on the Character of the Product and on the Energy Requirements. (Om inverken av Krossvalsars olika rotationshastighet pa krossproduktens beskaffenhet samt pa energiförbrokningen.) C. A. Landegren. *Jernkontorets Annaler*, Vol. 114, April 1930, pages 181–203.

A low grade Fe ore was treated in a crusher with rolls 400 × 260 mm. which could be run from 100 to 240 R.P.M. The weight and particle size of the material, the power requirements for each experiment, the R.P.M. of the cursher, the duration of the experiment and the screen analysis of the crushed material were all noted in the investigation. The screen analyses showed that the products were coarser for the higher R.P.M. and that the most even particle sizes were obtained with crushing quotients of about 2:1, this being the ratio of the maximum kernel size to the distance between the rolls. The percentage of fines is from 3–5% for a crushing quotient of 2 and from 11–16% for a crushing quotient of 10. The power requirements are found to follow the formula developed by Argall. The maximum was 8 kw.-hours per T and the minimum 0.3 kw.-hours per T. The greater the R.P.M. and the greater the crushing quotient the greater is the power requirement. The capacity of the crusher is found to be primarily dependent on the particle size of the material. HCD(20)

Accidents at Metallurgical Works in the United States (for Calendar Year 1928). W. W. Adams. (*Bureau of Mines, U. S. Dept. of Commerce, Technical Paper* 474.) United States Government Printing Office, Washington, D. C., 1930. $5^7/_8 \times 9^1/_8$ inches, 34 pages. Price, 10 cents.

This pamphlet is a yearly production of the Bureau of Mines. Unlike its predecessors, the current issue does not cover the field of plants which handle non-metallic minerals. It takes into consideration all ore-dressing and smeltering plants except iron blast furnaces.

A distribution is made of the accidents occurring among plants employing 45,695 workers. The report is supplemented by 30 tables, giving accident information in the metallurgical field covering the past seventeen years, which are completely cross-referenced by states, type of plant, men employed, type of accident, working days, etc.

These data were compiled from reports on schedules prepared by the Bureau of Mines, sent to and returned by operators of ore-dressing plants and smelters throughout the United States. They cover 433 ore-dressing plants, 107 smelters, 133 auxiliary plants which were active part or all of 1928. Additional tables give comparisons with by-product coke, petroleum, all types of quarries and coal mines.

While the total number of accidents for 1928 is 7% lower than that for 1927, 4698 accidents represent a large time loss. By using a scale adopted by the International Association of Industrial Accident Boards and Commissions, which deals with the time loss element of accidents, a table is given in this pamphlet which is pertinent enough to quote:

"Time lost through accidents

		Lost days
44	fatalities, at 6000 days each	264,000
2	permanent disabilities, at 6000 days each	12,000
179	permanent partial disabilities, at 800 days each	143,200
1311	serious temporary disabilities, at 32 days each	41,952
3162	slight temporary disabilities, at 6 days each	18,972
	Total (4698 accidents)	480,124

The foregoing figures indicate an average of 102 days as the lost-time equivalent of each accident in 1928." If this is transferred into work, it becomes equal to 1600 men being idle for one year of 300 working days.

The Bureau of Mines comes to the conclusion that the larger the plant and the more continuous the operation, the lower is the number of accidents occurring. (20)

Spring Steel by the Hard Process. *Mainspring*, Vol. 3, March 1930, 3 pages.

A short and informal discussion of the method of making spring steel by the "hard process." (20)

The Production of Iron Castings for Enameling. J. H. D. Bradshaw. *Foundry Trade Journal*, Jan. 9, 1930, Vol. 42, pages 32, 34.

It is important to have the correct composition of the metal, for the coefficient of expansion will vary and cause chipping of the enamel. Ideal iron for the purpose should contain: Total C 3.5–3.7%; Si 2.50–3.0%; Mn 0.30–0.50%; S 0.060–0.090%; and P 1.40–1.80%. The mixture should not contain any steel or cast iron scrap. Patterns should be of uniform thickness to eliminate "hard areas." Good molding sand for the purpose will contain approximately 90% silica and 10% alumina. After pouring castings should be removed as quickly as possible to eliminate sand spots. In preparing castings for enameling, surface should not be made too smooth as the enamel will not adhere. Pickling process should not be used because it produces a blistered surface. Recommends sand blasting. VSP(20)

Steel Treaters in Winter Meeting. *Iron Age*, Feb. 13, 1930, Vol. 125, pages 515–517.

Report of meeting of the American Society for Steel Treating held at New York, Feb. 7 and 8. Gives abstracts of paper presented on alloy steels for forging and structure; and continuous furnace for normalizing. VSP(20)

Failure of Steel Castings and Forgings. Robert A. McGregor. *Foundry Trade Journal*, Feb. 13, 1930, Vol. 42, page 120.

Abstract of a paper read before the North-East Coast Institution of Engineers and Ship-builders. Discusses failures due to fatigue. Considers appearance of fatigue fracture and outlines conditions likely to induce fatigue; notably bad alignment of rotating parts in their bearings, nonmetallic inclusions, excessive heat gradients and advanced corrosion. VSP(20)

Confessions of Ignorance. H. W. Gillett. *Metals & Alloys*, April 1930, Vol. 1, page 445.

An editorial. A summing up of the observations which yields a clear perspective of comparison of older data with the more recent is pointed out as helpful in indicating the insecure margins of our knowledge and, therefore, helpful to indicate the way to further study. ESC(20)

The Commercial Standards Service and Its Value to Business. *Commercial Standard CSO*-30, March 30, 1930, Bureau of Standards (Sold by Supt. of Documents), Washington, D. C., 10¢.

Description of mechanism set up by which industry may voluntarily decide upon specifications, nomenclature, definitions, grading rules, dimensional requirements and tests, and, when a sufficient proportion of the industry has accepted the standards, have them published as Commercial Standards, by the Government. Lists are made up for distribution, of those firms that are willing to certify that their goods meet those standards. Metallurgical products for which commercial standards are in effect are steel, wrought iron and brass pipe nipples, malleable or steel screwed unions, builders templet hardware, and diamond core-drill fittings. HWG(20)

List of Books, Bulletins, Journal Contributions and Patents by Members of Mellon Institute of Industrial Research during 1929. L. Heaton. *Mellon Institute Bibliographic Series, 3rd Supplement to Bulletin* No. 2.

Lists bulletins, reports, papers and patents. Most of these refer to such things as cascara, moths, hot dog casings, soaps and other organic materials. Of metallurgical interest are publications on cast iron by Marbaker, and on plating upon aluminum by Work. HWG(20)

Pittsburgh Aeronautic Meeting. *Metals & Alloys*, April 1930, Vol. 1, pages 464 and 470.

A brief summary is presented of papers presented before the Symposium on Metal Airplanes at the Pittsburgh Aeronautic Meeting, of the Aeronautic Division and Pittsburgh Section of the American Society of Mechanical Engineers and the Engineering Society of Western Pennsylvania. ESC(20)

Research, the Parent of Specifications. H. W. Gillett. *Metals & Alloys*, April 1930, Vol. 1, page 445.

An editorial. A justification for more and better specifications. ESC(20)

Ocean Shipment of Ferrosilicon. *Metals & Alloys*, Feb. 1930, Vol. 1, pages 373–376. Comment, May 1930, page 492.

Summarized from a report by the Bureau of Mines and Bureau of Standards to the Steamboat Inspection Service. In the early days of ferrosilicon manufacture a shipment over the North Sea disintegrated and caused fatalities among the men on the ship. It seems that ferro-silicon carries no shipment hazard in the ranges of 0–30% and 70–100% and likewise 45%. In the range of 52–55% silicon there is real danger. Any composition of iron and silicon is called ferro-silicon and any composition might find metallurgical use to introduce silicon into iron and steel. Up to 15% silicon is made in the blast furnace and higher compositions are made by electric smelting. The steel scrap of iron ore used always contains some phosphorus. It cannot be kept below 0.01–0.03%. The silica may contain lime and calcium phosphate. The latter will be reduced at the high temperatures under the action of the carbon. The phosphorus then may be present as iron phosphide, aluminum phosphide or calcium phosphide or combinations of these. (Aluminum due to alumina present in silica.) The latter react with the moisture readily. Phosphorus is readily removed from the surface of ferrosilicon by moist air. If it is crushed, broken or disintegrated in handling fresh surfaces are exposed. If there were no tendency toward spontaneous disintegration of ferrosilicon there would be no hazard in the ocean shipment. This disintegration is at a maximum at 52–55% since this composition crystallizes in large leaf-like crystals. The tendency to crumble is very slight up to 75% Si, but above that there is none at all. Phragmens and Murakami recently determined the iron silicon diagram and they indicate no likelihood of disintegration of ferrosilicon at 45–50% silicon. Disintegration appears to be due to some internal phase change which takes place with change of volume and thus results in crumbling. Slowly cooled alloy is more susceptible than the rapidly chilled variety. Aluminum, calcium and phosphorus are the impurities to guard against. The 52-55% of Si grade should not be permitted in ocean shipment at all. It is recommended that standardization of the 48% or 45% silicon be made. There seems no need for restrictions on material below 45% or above 70%. The 33–35% should not be proscribed for there is no evidence that it is hazardous. It is believed that 45–48% or 65–70% Si stored for one month will remove any harmful phosphorus from the surface. If the tendency to crumble is not then apparent it will normally never appear. It is not feasible to study the problem on an experimental scale. The modified regulations adopted by the Supervising Inspector General of the Steamboat Inspection Service are stated and a bibliography is appended. ESC(20)

Development and Prospects of the German Cast Steel Industry. (Entwicklung und Aussichten der deutschen Stahlgussindustrie.) R. Krieger. *Stahl und Eisen*, April 3, 1930, Vol. 50, pages 421–422.

Address before the 10th annual meeting of the *Verein deutscher Stahlformgiessereien*, April 3, 1930, Düsseldorf. The paper especially refers to the improvements of cast steel by alloying and heat treatment. GN(20)

Blistering Phenomena in the Enameling of Cast Iron. A. I. Krynitsky & W. N. Harrison. *Bureau of Standards Journal of Research*, June 1930, Vol. 4, page 757–807; *Journal American Ceramic Society*, Vol. 9, Jan. 1930, pages 16–61; Extended abstract in *Metals & Alloys*, Vol. 1, Aug. 1930, pages 663–666.

In the application of vitreous enamel to cast iron, "blisters" may form on the enamel. The Bureau of Standards, in response to a request from the American Ceramic Society, undertook a study of this phenomenon and obtained data from which the following conclusions were drawn. Physical defects in the castings, especially "sponginess," will cause blisters, as will also faulty composition or application of enamels. There are, however, differences in the tendencies of different sound castings to give blisters when enameled under identical conditions. The gases forming these blisters are CO and CO_2. A gray iron casting acquires in freezing and cooling a very thin surface skin or "microchill," of varying thickness and hardness. The data indicate that removal of this skin from sound castings eliminates blistering. During the enameling process the combined carbon of this skin tends to break down to a nascent, readily oxidizable form of carbon, which evolves CO and CO_2. There are probably two kinds of non-blistering iron, one in which little combined carbon is present at the surface, and another in which it is stabilized. Some irons are more prone to give the "microchilled" layer than others. During the early stages of enameling both blistering and non-blistering irons evolve gas, which is attributed to quick oxidation of submicroscopic graphite and which escapes before the enamel has fused to a retentive condition. Addition of graphitizing agents, such as silicon, may be beneficial, but it is harder to prevent the formation of the microchill than the ordinary, or macrochill. Removal of the surface layer by deep sandblasting or "burning out" appears to be the most practical remedy for blistering of sound castings. Bibliography of 30 references. WHK(20)

LABORATORY APPARATUS (21)

Note on Molybdenum Wire-Wound Furnaces. C. Sykes. *Metal Industry*, London, Nov. 1, 1929, Vol. 35, pages 415, 418.

Condensed from paper presented before the Refractory Materials section of the Ceramic Society. The Molybdenum wound furnace is the most suitable for research over a temperature range 1100–1650°C. Gives a brief description of the furnace. The furnace is operated with top and bottom cap in position since more satisfactory gas circulation can be obtained. It compares favorably with the nichrome furnace. VSP (21)

FOUNDRY PRACTICE & APPLIANCES (22)

Overcoming Alloy Ingot Troubles in Brass Foundry. Wm. E. Paulson. *American Metal Market*, Vol. 37, May 22, 1930, page 3.

A non-technical discussion of the difficulties experienced by one foundry in producing non-ferrous castings using alloy ingots. WHB(22)

Recent Developments in Cast Iron and Foundry Practice—Malleable Cast Iron. F. K. Neath. *Bulletin British Cast Iron Research Association*, April 1930, pages 250–253.

A correlated abstract on recent German developments. The following are considered: high quality malleable cast iron; manganese content; annealing; annealing boxes and annealing furnaces. (22)

Impression Instruments for Measuring the Strength of Foundry Sands H. L. Campbell. *Instruments*, Vol. 2, July 1929, pages 243–244.

Describes a simple compression machine for molding sands utilizing a spiral spring which is compressed to apply the load. (22)

Absorbed Moisture Lowers Core Strength. C. E. Shubert. *Foundry*, Vol. 57, Sept. 1, 1929, pages 733–734, 764.

Tests on dried sand cores show that the moisture absorbed when cores are allowed to stand in a damp mold decreases the strength of the core. Contrary to popular belief oil sand cores absorb moisture in this way. (22)

The Stability Ranges of Certain Bonds. J. H. Chesters & W. J. Rees. *Bulletin British Cast Iron Research Association*, April 1930, pages 241–243.

The main reactions which occur during the baking of an oil sand core are: (1) the evaporation stage-loss of the volatile part of the bond; (2) the oxidation stage, in which bonds of the linseed oil type are oxidized to complex organic compounds; (3) the beginning of the carbonization of this resin, yielding coke. The paper describes experiments made to determine the ranges over which these reactions occur. Rod shaped cores were molded and baked and then held under a tension of about 8 lbs./in.^{2} and their temperature raised about 10° C. per minute. The extension of the rod was automatically recorded and the failure curves and temperatures determined. (22)

Molding Sands. George M. Enos. *Metals & Alloys*, Vol. 1, May 1930, pages 496–501.

A general discussion is presented of the nature and occurrence of molding sands. The variables connected with the properties of molding sand are listed and classified. The usual tests applied to molding sands are described and proper interpretation of data is indicated. ESC(22)

Science **Hand in Hand with Labor.** F. Hudson. *Transactions American Foundrymen's Association*, Vol. 37, 1929, pages 417–450 & 669–670; *Foundry*, Vol. 57, Aug. 1, 1929, page 643; Aug. 15, 1929, page 688.

Discusses the control of cupola practice and mixtures to avoid shrinkage troubles and porosity in castings. The importance of correct casting temperature is emphasized. The testing of molding sands and sand mixtures is also discussed. (22)

An Analysis of the Performance of Fifty-Four-Inch Cupolas Based upon Records of Practical Operation. Edward E. Marbaker. *Transactions, American Founrymen's Association*, Vol. 37 (1929), pages 71–90, 678–682; *Foundry Trade Journal*, Vol. 42, Feb. 27, 1930, pages 155–156, 165.

Considers replies received to questionnaires from 136 representative concerns on conditions surrounding actual practical cupola operation. The question arose as to the correct method of expressing output of cupola. In each case the weight of iron melted has been taken as that of the total charge minus the drop. Figures for straight-lined cupolas of 54 in. diameter inside the lining is 10–12 tons. The melting rate of cupolas lined to 54 in. and boshed to a smaller diameter in melting zone is different. The highest rate recorded for this group was 10.52 tons for cupola boshed to 48 in. minimum diameter and lowest rate was 4.36 tons for a minimum bosh diameter of 50 in. It appears that boshed lining decreases normal melting rate. Author claims that presence of bosh is advantageous from standpoint of combustion. Thermal efficiency of cupola is affected by temperature at which iron is delivered at the spout. The variation in coke consumption is from 1,200 to 4,500 lbs. for straight-lined cupolas and from 950 to 2,650 lbs. for boshed cupolas. There seems to be no connection between type of castings and thermal efficiency. Coke ratio has slight relationship to actual thermal efficiency. Air supply is considered in detail. VSP(22)

Casting **Cylinders in Green Sand.** D. J. Campbell. *Machinery*, April 1930, Vol. 36, page 591; Discussion S. A. E. Journal, Vol. 27, July 1930, pages 91–92.

Abstract of a paper presented before the Society of Automotive Engineers, Detroit, January 1930. RHP (22)

The **Future of British Foundries, with Special Reference to Continuous** Castings. A. S. Beech. *Foundry Trade Journal*, Jan. 16, 1930, Vol. 42, pages 45–51.

Paper read before the Wales and Manmouth, West Riding of Yorkshire, and the Newcastle branches of the Institute of British Foundrymen. Stresses importance of adoption of the continuous casting system and the adequate training of apprentices in British foundries. The advantages of using the continuous system are: (1) greatly increased output; (2) floor space is used over and over again. (3) cost of castings is reduced; (4) castings are more accurate and scrap castings reduced; (5) wages increased; (6) continuous use of same molding boxes. Describes the operation of the continuous system in detail. Numerous illustrations are included. VSP (22)

High-Duty Cast Iron. A. Mele & G. Calbini. *Foundry Trade Journal*, Feb. 13, 1930, Vol. 42, page 116.

Brief abstract translation of article in *La metallurgia Italiana*. Considers Lanz, Emmel, "Sternguss" and duplexing processes of making high quality castings. Influence of these processes on matrix and graphite formation. Include table giving development of tensile strength of cast iron from 1870 to date. VSP(22)

Report New Method in Aluminum Casting. *American Metal Market*, April 18, 1930, Vol. 37, page 4.

Note describes a new method of casting in which the molten aluminum is cast into molds made of composition metal and constructed in two parts. When pouring is completed a blast of cold air is blown against the outside of the mold for about one minute, thereby cooling and contracting the metal. Savings of 60% in labor and of 25% in total manufacturing costs, including labor, are claimed. WHB(22)

Foundry Patterns of Wood, Commercial Standard SC19-30, April 7, 1930, Bureau of Standards. (Sold by Supt. of Documents), Washington, D. C., 10 ¢.

The standardization of color markings on patterns and core boxes jointly sponsored by several technical societies, now appears as a Commercial Standard. The colors are: surfaces to be left unfinished, black; to be machined, red; seats for loose pieces, red stripes on yellow; core prints and seats for loose prints, yellow; stop-offs, diagonal black stripes on yellow. Large size color charts can be obtained from the American Foundrymen's Association, 222 West Adams Street, Chicago. HWG(22)

Steel Castings in Green Sand. Paul R. Ramp. *Iron Age*, Mar. 6, 1930, Vol. 125, page 711–713.

To produce sound and smooth steel castings in green sand, several things must be considered: character of the sand; facing sand mixture; mixing and care of heap sand; pattern making; venting, gating, size and location of feeding heads; use of gaggers and rods and the method of pouring. Sand should be similar to Ottawa or New Jersey silica sand. It should be coarse enough to allow gas to escape from the mold. Silica content should not be under 96%. Discusses method of casting. VSP(22)

More Interesting Moulding Jobs. E. Longden. *Foundry Trade Journal*, Feb. 27, 1930, Vol. 42, pages 157–160.

Includes discussion. Paper read before the Birmingham, Coventry and West Midland branch Institute of British Foundrymen. Compared methods of pouring and gating castings. Dealt with feeding points and molding operations. Making of heavy castings detailed. Contains many illustrations. VSP(22)

Blast of Cupola Enriched with Oxygen. (Sauerstoffanreicherung des Gebläsewindes im Kupolofen.) F. Morave. *Stahl und Eisen*, April 3, 1930, Vol. 50, page 452.

Abstract of a paper in *Giesserei*, 1930, Vol. 17, pages 132–136 and 155–167. As results from the table below show, best results were obtained with an excess of 2.87% oxygen in the blast.

%O$_2$ No. of Test	Content of Blast	% O$_2$ Enrichment	Coke by C/100 kg.	Consumption Saving %	Melting kg./hour	Output Increase %
2	20.9		7.95		5507	
5	22.26	1.36	7.55	5.30	6000	9.09
6	22.94	2.04	7.31	8.70	6717	22.13
7	23.77	2.87	6.77	17.43	8081	46.93
8	24.11	3.21	7.26	9.50	6492	18.04
9	25.36	4.46	7.37	7.87	6604	20.07

Iron loss by oxidation amounted to 0.24–0.60% in normal practice from 0.12–0.51% with oxygen rich blast. The pick up of sulphur decreased from 89.4 and 63% to 48.4 and 35.7%. The economy of an enrichment of oxygen was calculated. GN(22)

The Flow of Metal in Molds. George M. Enos. Part I. *Metals & Alloys*, Feb. 1930, Vol. 1, pages 362–364; Part II, March 1930, pages 417–419.

Outline of variables in foundry practice lists some of the points wherein deviation from good practice may cause the production of inferior castings. Molds and cores must be vented to permit elimination of gases, designed to accommodate the pressure of the molten metal and the channels must be sufficiently large to permit filling of spaces due to shrinkage. Risers and re-inforcements must be provided to eliminate sand freed by abrasion of flow and prevent destruction of mold. Copes, chaplets, wires and bolts carefully placed aid greatly in re-inforcement of mold structure.

In the pouring and solidification of gray cast iron, liquid water changes to steam, organic materials are burned to gases, molten metal solidifies and graphitic precipitation occurs within the solid metal. These changes of state may cause defective castings. Vents and risers assist in the elimination of the gases. Control of the temperature of superheat to accommodate the weight of metal, the specific heat, the rate of pouring, the ratio of surface to volume of casting must be considered. Gates and risers should be located with a clear understanding of the principles of the flow of liquids such that adequate accommodation of shrinkage due to solidification will be accomplished. ESC(22)

FURNACES & FUELS (23)

Losses through Leaky Doors in Open Hearths. (Fürluster genom otäta ugnsluckor vid martinsugnar.) B. A. Afzelius. *Jernkontorets Annaler*, Vol. 114, April 1930, pages 169–180.

Mathematical discussion. HCD(23)

European Developments in Electric Furnaces for Annealing Non-Ferrous Metals. M. Tama. *Fuels & Furnaces*, Vol. 8, Jan. 1930, pages 65–68; *Engineering*, Vol. 128, Sept. 20, 1929, pages 389–391.

From paper before Institute of Metals Entitled "Progress in Electric Furnaces for Non-Ferrous Metals." See *Metals & Alloys*, Jan. 1930, page 345. MS(23)

30-Ton Electric Steel-Melting Furnace. *Engineering*, Vol. 129, March 14, 1930, page 360.

Describes furnace made by Messrs. Watson's (Metallurgists), Ltd., Sheffield. It is operated on the Greaves-Etchells system whereby heat is applied both above and below the bath thus obtaining an even temperature throughout mass of molten metal. Hearth lining is mainly of dolomite and magnesite. Describes tilting system and method of supplying electrical energy. Gives photograph of furnace. LM(23)

Heat Economy in Metallurgical Furnaces. Sir Robert Hadfield & R. J. Sarjant. *Engineering*, Vol. 128, Nov. 22, 1929, page 684.

The paper included a summary of recent advances in the application of heat-resisting alloys to recuperators. The introduction of steels of the high-nickel, high-chromium type has rendered possible the use of pre-heats as high as 900° C. as compared with a maximum of 350–400° C. possible with the older cast iron and mild steel recuperators. The same type of steel is being successfully employed for regenerators, the heat capacity per unit volume being nearly three times that of firebrick. (23)

The Application of Correct Gas-Flow Principles in Furnaces. Edward J. Plumley. *Iron & Coal Trades Review*, Jan. 17, 1930, Vol. 120, pages 71–74.

A paper read before the Cleveland Institution of Engineers at the Technical Institute, Middlesborough, Jan. 7, 1930. Reviews the laws governing the movement of gases in furnaces. Discusses furnaces for reheating and heat treatment, other types including open-hearth are omitted. Gases should be admitted at the top of the furnace and withdrawn through ports at the level of the hearth. If the ports are not in the lowest part of the furnace its efficiency is lowered. Discusses the effect of the different pressures in the furnace, the furnace crown and convection currents on the flow of the gases in the furnace. The tail end of the flame should be in contact with the stock to get the work done and to protect the stock from oxidation. Gives some information of particular interest in the operation of the following types of furnaces: 1. Shallow pack continuous annealing furnace; 2. Under-fired annealing furnace; 3. Vertical gas furnace; 4. Continuous annealing furnace; 5. Chantraine axle-annealing furnace. 6. Furnace for annealing sheets or thin plates. Construction and control of furnaces along the lines suggested in this paper would reduce coal consumption to an appreciable extent. RHP(23)

The Electric Annealing Furnace. James Kniveton. *Iron & Steel Engineer*, Vol. 7, Mar. 1930, pages 135–141.

Includes discussion. A review of the use of electric heat in annealing; ts basis for competing against fuel: better work not lower costs. Discussion centers about control of temperature and atmosphere. WHK(23)

Construction, Operation and Organization of Modern Coking Plants Principally in Germany and Czechoslovakia. (Construction, Exploitation, Organisation des cokeries modernes specialment en Allemagne et in Tcheco-Slovaquie.) Ch. Berthelot. *Revue de Metallurgie*, Vol. 27, April 1930, pages 177–193.

Coal production in Europe increased only 1% from 1913–1928 due to the development of liquid fuels, water power and increase in combustion efficiency resulting together in yearly savings of 400 million tons. In coking practice the general tendency is to build larger ovens and to use some low grade gas for their heating, directing coke gas for other purposes. A description of German, Czechoslovakian, Dutch and Belgian plants is given. The trend toward larger installations and better utilization of by-products is more pronounced here than in France. A description of some new German plants and operations of them is given in detail. JDG(23)

Investigations in Annealing Plants. (Untersuchungen in Glühereibetrieben.) G. Bulle. *Archiv für Eisenhüttenwesen*, Vol. 3, May 1930, pages 693–708.

Report No. 75 of the Rolling Mill Committee of the Verein deutscher Eisenhüttenleute. After a theoretical outline on heat transfer in annealing, many practical examples are referred to permitting the conclusion that annealing plants generally need a better supervision for producing uniform materials. Annealing furnaces and temperature control have to be improved. Process and conditions of annealing must be better known for each individual material to be annealed. The development of a suitable standard practice is essential in each case. Tests on correct measurements in practice for a better handling of the annealing process and investigations on the flow of heat in individual materials are recommended with special reference to size, kind and packing method of the material, to containers, and its location in the annealing furnace, the construction of the furnace and its supervision. GN(23)

The Ajax-Wyatt or Vertical Ring Induction Furnace as Applied to Melting Non-Ferrous Metals. William Adam, Jr. (Ajax Metal Co.) *Preprint* 57–14, *American Electrochemical Society Meeting*, May 29–31, 1930, pages 143–164.

The specifications for an ideal electric melting furnace are laid down, and operating data are presented to show that the vertical ring induction furnace more nearly meets these specifications than any other type of furnace. With this furnace thermal efficiencies as high as 85% have been obtained. There are few large power consuming devices that have as smooth an operating curve as the vertical ring induction furnace. The stirring action is due to the combined motor, pinch and joule effects. The power input of the vertical ring induction furnaces varies from 45 kw. to 150 kw. and the pouring capacity from 400 to 2,200 pounds (180–1,000 kg.) per heat. Single phase is preferable to polyphase, on account of its extreme simplicity. (23)

Induction Furnaces. *Electrician*, Vol. 103, May 30, 1930, page 712.

The Metropolitan-Vickers Electrical Co. has developed a small induction furnace equipment particularly suited to laboratory work. The furnaces will melt charges of up to $^{1}/_{2}$ lb. in 2–3 minutes, while the normal full charge is melted in 20–30 minutes. All the furnaces will melt quantities up to about twice their normal charge, provided that a correspondingly longer time is allowed for the operation. WHB(23)

Industrial Heating for Heat Treatment. Robert M. Keeney. *Metals & Alloys*, Vol. 1, May 1930, pages 508–513.

Heat treatment is an operation or combination of operations involving the heating and cooling of a metal or an alloy in the solid state for the purpose of obtaining certain desirable conditions or properties. Quality requires uniform application of heat to the entire surface of the charge, heating at the proper rate to the proper temperature, and holding the charge at the correct temperature for a period of time necessary for complete saturation. Uniformity of temperature cannot be obtained in a box or batch type furnace. A high degree of uniformity is obtained in immersion heating and in air tempering with automatic circulation of the furnace temperature. A graph is shown which indicates the temperature ranges of the normalizing as well as annealing and hardening ranges of various carbon steels. Practical heating usually occurs slightly above these points to overcome the lack of uniformity of temperature. Various temperatures observed in box type furnaces are tabulated. These data, demonstrate a superiority of uniformity for the underfired furnace as compared with the side fired and the direct fired furnaces. A discussion of the relation of heat transfer and the deformation of the work due to localized heating is presented. Observations on time of heating and the effect upon shape, grain structure are presented and analyzed.

ESC(23)

Developments in Fuel Economy at Skinningrove. Frank Bainbridge. *Journal Iron & Steel Institute*, May 1930, *Advance Copy* 2, 23 pages.

The author gives a brief description of improvements in blast furnace practice designed to make available greater quantities of surplus gas by the installation of automatic burners on stoves and boilers, the further quantities so liberated being made use of in the production of steel. Economies have also been achieved by the application of coke-oven gas to the open-hearth furnaces through water-cooled ports or burners. Supplies of cleaned blast-furnace and coke-oven gases have been utilized by mixing them direct with the producer gas, this being made possible by the careful control and measurement of the volume and by the installation of simple diaphragm-type meters and electrical regulators. AEH(23)

Heat Value, Flow of Heat and Gases, the Physical Principles of Metallurgical Processes. (Wärmewertigkeit, Wärme-und Gasfluss die physikalischen Grundlagen metallurgischer Verfahren.) H. Bassen. (Friedrich Krupp A.G. Rheinhausen.) *Stahl und Eisen*, Vol. 50, May 15, 1930, pages 668–678.

Paper before the Annual Meeting of the Verein deutscher Eisenhüttenleute, May 17, 1930. The report stresses the importance of the physical principles for metallurgical processes of the steel industry. The influence of preheated gas and air in using fuels for metallurgical processes is demonstrated by a heat-temperature diagram. As examples of metallurgical processes in which heat is of importance the metallurgy of the blast furnace, the sponge iron melting process and the open hearth process are considered, and heat-temperature diagrams of these processes are given which permit one to judge by this means the metallurgy of the mentioned processes. Furthermore, the knowledge of the theoretical principles of heat and gas flow is pointed out to be of importance for metallurgical processes. The flow of gas, air and waste gases of a furnace can be calculated thus making possible a complete utilization of fuels. In considering the flow resistance the charge of a shaft furnace offers to gases, the necessity of a good porosity of the charge for gases is stressed. This factor has its bearing on the efficiency of a furnace. The segregation of carbon in the shaft of a blast furnace is calculated. GN(23)

Experience with Coal-Fired Pot Annealing Furnaces. (Beiträge zu den Erfahrungen in kohlegeheizten Topfglüherien.) H. Stabler. *Stahl und Eisen*, March 27, 1930, Vol. 50, pages 381–391.

Report No. 74, of the Rolling Mill Committee of the Verein deutscher Eisenhüttenleute. A survey of experiences, obtained from numerous German plants, in annealing wire and hoop in coal fired cylindrical pots is given. As many discrepancies were found in the data of this questionnaire the author carried on experiments on annealing time, kind of pots and fuel consumption. The course of temperature within the material to be annealed and the time of annealing were especially investigated; the results of these tests are plotted in diagrams. After determining the annealing times necessary for various materials (borings, wire, rivets, hoop steel, massive steel rings) the efficiency of pot annealing was calculated on the basis of the coal consumption per hour. GN(23)

The Influence of Furnace Design on Metallurgical Processes. (Ueber den Einfluss der Ofengestaltung auf metallurgische Umsetzungen.) E. J. Kohlmeyer. *Metall und Erz*, Jan. 1930, Vol. 27, pages 1–9.

Includes discussion. A review of progress made in furnaces used for melting and refining non-ferrous metals. Design and gas absorption are important. Three designs involved distinctly new features, the Bessemer converter, the blast furnace for lead and the Dwight process and rotary furnaces and the Waltz process. Many processes have been accelerated. Describes the roasting under blast of Pb and Zn ores, the difficulty of intensifying endothermic processes, dezincification processes and rotary furnaces which can be used for refining and reducing oxides. CEM(23)

Electric Furnace Development. *Foundry Trade Journal*, Jan. 9, 1930, Vol. 42, pages 29–30.

Discussion of a paper on "Metal Melting by Electricity" by D. F. Campbell and W. S. Gifford read before the Institute of British Foundrymen. See *Metals & Alloys*, Mar. 1930, page 431. VSP(23)

New Experiences with Maerz Open Hearth Furnace Constructions. (Neuere Erfahrungen mit Siemens Martinöfen, Bauart Maerz.) E. Killing. *Stahl und Eisen*, Aug. 1, 1929, Vol. 49, pages 1121–1132.

Report No. 170 of the Steel Mill Committee of the Verein deutscher Eisenhüttenleute. Includes discussion. The report summarizes former experiences with the Maerz furnace and describes the historical development of this type of open-hearth furnace. The results in examining a Maerz furnace of the latest type are given in detail, especially as to the heat efficiency. In summarizing the author states that the advantages of the Maerz furnace exceed its disadvantages. GN(23)

REFRACTORIES & FURNACE MATERIALS (24)

Refractory Bricks. A. Jaeschke. *Engineering*, Vol. 129, March 21, 1930, pages 390–392.

Discusses following properties which refractory materials should possess: high softening and melting points, high resistance to large and rapid temperature changes, resistance to chemical corrosion, little liability to change of shape and dimensions in service, good thermal conductivity, uniform composition and uniform quality in manufacture, high resistance to mechanical stress, easy dressing for constructional purposes, exact and uniform dimensions, and smooth and plane surfaces. Needless to say, no one refractory material will fulfill all these requirements but a material must be selected which will best suit the purpose for which it is intended.

LM(24)

GASES IN METALS (25)

Unsoundness in Bronze Castings. Edward J. Daniels. *Journal Institute of Metals*, *Advance Copy* 515 (1930), 18 pages; *Engineering*, Vol. 129, Mar. 14, 1930, pages 358–360; *Engineer*, Vol. 149, Mar. 21, 1930, pages 320–321.

The author has investigated the effect of some pure gases on the soundness of bronze castings and describes the casting in sand molds of metals subjected to various melting treatments. He suggests a tentative explanation of the cause of unsoundness occurring in practice. The experiments made confirm the results of the work of Karr and Rawdon, and of Carpenter and Elam, regarding the relationship between casting temperature and unsoundness of bronzes. Other conditions remaining constant, variations in casting temperature were found to affect the rate of solidification, and similar variations in rate of solidification obtained by constant casting temperature into molds of different materials also affect the density of castings in the same way. Nitrogen, carbon monoxide and carbon dioxide were found to be neutral towards bronze. Hydrogen was found to be a cause of unsoundness in bronze at certain rates of solidification and it was found to be possible to suppress this unsoundness by treatment with neutral gases. It is suggested that the unsoundness normally found in bronze castings is due to the combination of hydrogen and oxygen in the molten bronze. The presence of hydrogen alone causes defects of a different character. Melting in pot furnace with a thin fuel bed and a good draft, as compared with melting with a thick fuel bed and a poor draft, was found to improve the density of sand castings. This was the case with pure copper but the results were much less favorable. Degasification with nitrogen, deoxiders and pre-solidification in order to improve the density was unsuccessful, but the strength of the alloy appeared to be increased by pre-solidification. AEH & LM(25)

Experiments on the Influence of Gases on the Soundness of Copper Ingots. N. P. Allen. *Journal Institute of Metals*, *Advance Copy* 514 (1930), 44 pages; *Engineering*, Vol. 129, April 4, 1930, pages 457–461; *Engineer*, Vol. 149, Mar. 21, 1930, pages 320–321.

The author has examined the serious unsoundness which is caused in ingots by the presence of hydrogen in the molten copper from which they are cast, and methods for avoiding this unsoundness are described. It is maintained that the unsoundness found in commercial ingots is not due solely to the presence of hydrogen but to the combination of hydrogen and cuprous oxide which react in the metal and form steam as solidification takes place. This reaction is difficult to suppress so long as cuprous oxide is present in the metal. In order to produce sound castings it is necessary to add elements which will reduce the cuprous oxide. Carbon monoxide, carbon dioxide and nitrogen were found to be inert so far as the formation of blowholes is concerned. The above statements are supported by experimental evidence and a method of studying the equilibria between hydrogen and cuprous oxide when present in molten copper is described. The difficulties have not all been worked out with regard to this method and the author expects considerable modification in detail will be necessary in future work. AEH & LM(25)

On the Determination of Gases in Metals with Special Reference to the Determination of Oxygen in Iron and Steel by Means of the Vacuum Extraction Method. Part II: Application of the Method; Segregations of Oxygen; Oxygen Content and Metallographic Examination. (Zur Bestimmung der Gase in Metallen, besonders des Sauerstoffs in Eisen und Stahl nach dem Heissextrations Verfahren. II. Teil: Anwendung des Verfahrens; Sauerstoffseigerung; Sauerstoffwert und metallographscher Befund.) H. Diergarten. *Archiv für Eisenhüttenwesen*, Vol. 3, March 1930, pages 577–586.

Report No. 72 of the Chemists Committee of the Verein deutscher Eisenhüttenleute. After a general outline of the possibility of reducing oxides at higher temperatures the arrangement of the high frequency furnace and additional apparatus for reducing pure oxides is described. The oxygen content of samples from soft open hearth steels before and after adding ferro silicon and pure aluminum were determined. The influence of temperature in reducing oxides and the time of reducing is considered for steels deoxidized to various degrees. The disturbance of the vacuum-extraction method with high manganese and aluminum contents of steels is explained. The influence of shape and size of the samples for determining oxygen is considered. Figures are given for blank determinations. Check determinations gave very good results. Discrepancies of not more than 0.0002%–0.0005% were found. Segregations of oxygen were determined in the ingot of a common basic open hearth steel. The values of oxygen amounted from 0.013–0.052%. The segregation of oxygen was found to be larger than that of carbon, phosphorus and manganese. The segregation of oxygen is only little less than that of sulphur. Tests on the reduction of pure oxides, except in the case of silica, do not prove in a convincing manner the possibility of using the vacuum extraction methods for the quantitative determination of oxygen. A temperature of about 1550° C. seems to be sufficient for the reduction of all oxides. It was tried to line up the results of the oxygen determinations with metallographic observations. In final judgment the opinion is held that in spite of the short time necessary to turn out a determination, and besides other advantages, that the application loses in value by effects of evaporation of samples tested. Further research has to determine the limits of application of the method. GN(25)

Gases in Copper and Their Removal. W. E. PRYTHERCH. *Journal Institute of Metals, Advance Copy* 516 (1930), 8 pages; *Engineer*, Vol. 149, Mar. 21, 1930, pages 320–321; *Engineering*, Vol. 129, Mar. 21, 1930, page 384; *Foundry Trade Journal*, Vol. 42 (1930) pages 229–230.

This paper describes a series of experiments made to ascertain the effect of oxygen, hydrogen and sulphur dioxide on the soundness of copper castings. Previous workers have shown that the degree and nature of unsoundness caused by dissolved gases is greatly influenced by temperature conditions, rate of cooling and by the size and shape of the casting involved. The experiments carried out show that included gases may be partially removed by slow solidification followed by remelting the copper, by passing nitrogen or other inert gas through the molten metal and by melting *in vacuo*. The practicability of using oxygen to remove hydrogen in copper was investigated with negative results, mainly owing to the slow oxidation of the hydrogen, and the large excess of oxygen. The author recalls that the solubility of hydrogen and sulphur dioxide in copper is greatly reduced at the solidification temperature and points out that when heating is carried out in such a way to prevent these gases from coming into contact with the molten metal better castings can be produced.

AEH & LM(25)

Nitrogen in Iron. (Zur Frage des Stickstoffs im technischen Eisen.) Part I. On the Influence of Nitrogen on the Physical Properties of Technical Iron Especially on the Relation to Magnetic Aging. (I. Ueber den Einfluss des Stickstoffs auf die Eigenschaften des technischen Eisens insbesondere über seine Beziehung zur magnetischen Alterung.) W. KÖSTER. *Archiv für Eisenhüttenwesen*, Vol. 3, April 1930, pages 637–658; *Stahl und Eisen*, May 8, 1930, pages 629–631.

Report No. 162 of the Materials Committee of the Verein deutscher Eisenhüttenleute. Includes discussion. Nitrogen in steels is retained in supersaturated solid solution even in cooling slowly. Nitrogen segregates only on heating to low temperatures. It takes about 2 weeks at 100° C. to complete the segregation. The change of the magnetic properties during this process of segregation is most remarkable. The isothermal change of the magnetic properties and the electric conductivity was studied with 13 slowly cooled basic Bessemer steels of the composition: C 0.06–0.12%, Si 0.01%, Mn 0.26–0.88%, P 0.034–0.102%, S 0.042–0.096%, Cu 0.03–0.26%, N 0.009–0.21%. The steels were aged for different times at the following temperatures: 65° C., 150° C., 200° C., 250° C., 300° C. and 400° C. The coercive force increases mostly at 100° C., 3.6 gausses on aging for 1/2 hr., 8.9 gausses on aging for 15 days. At higher aging temperatures the values of coercive force reach a maximum and decrease with the time of aging. Changes do not occur at those temperatures at which the solubility of nitrogen corresponds to the nitrogen content of the steel. The increase of coercive force corresponds to an increase of electric conductivity, with the highest values for 100° C. The change of coercive force, however, in relation to the weight unit of nitrogen decreases quickly with the aging temperature, that means the quantity of nitride segregations increases with increasing aging temperature. These statements are proved by investigations on the structure. Nitrogen segregates at 100° C. in the shape of fine points, at higher temperatures in the form of needles. The change of coercive force of various steels under similar aging conditions is proportional to the nitrogen content of the steels. A similar relation holds for the change of electric conductivity. Segregation of nitrogen results in an essential decrease of tensile strength and hardness; number of twists and solubility in acids increase considerably. The influence upon elongation and reduction of area is not remarkable. The transition field of the notch toughness from low to high values is altered in so far as the high values of notch toughness are increased somewhat. The following table gives the change of some properties effected by a segregation of 0.01% nitrogen at 100° C. aging.

	Change per 0.01% N after aging at 100° C.
specific electric resistance	$-0.0013\ \frac{\Omega.\text{mm.}^2}{\text{m}}$
coercive force	+3.2 gausses
tensile strength	—2.3 kg./mm.^{2}
number of twists	+25%
velocity of acid solubility	+20%

The nitrogen content causes the difference of physical properties between open-hearth and basic Bessemer steels. The solubility of nitrogen in common steels amounts to 0.001% at 100° C., 0.005% at 200° C., 0.01% at 300° C. and 0.02% at 400° C. The metallurgical process has an influence on the segregation of nitrogen. Magnetic aging is unknown for acid open-hearth steels and special basic steels, as for instance Izett-steel. The solubility of nitrogen in steels can be increased by adding silicon and aluminum to steels.

GN(25)

Nitrogen in Iron. (Zur Frage des Stickstoffs im technischen Eisen.) Part II. The Nature of the Force Influence Lines. (Das Wesen der Kraftwirkungsfiguren.) W. KOSTER. *Archiv für Eisenhüttenwesen*, Vol. 3, April 1930, pages 649–658.

The author in his article lines up the cold deformation figures, as revealed by Fry's etching method, with the segregation of nitrogen and gives a most convincing explanation for a well-known phenomenon, but nevertheless unrevealed in its causes. The article proves that the segregation of nitrogen in supersaturated solid solutions of α-Fe is accelerated by cold deformation. The blackening, as caused by etching, within the fields of deformation is explained by a difference of the velocities of segregation in deformed and non-deformed areas. The accelerated segregation of nitrogen by cold deformation proceeds in the field of cold deformation along the gliding planes. The appearance of deformation figures after annealing above the temperature at which the amount of nitrogen present is completely dissolved, depends upon the cooling velocity. Areas deformed to a smaller extent than necessary for recrystallization retain even after annealing at higher temperatures, the properties of deformed materials. The segregation of nitrogen can be supressed by quenching. Recrystallized grains do not precipitate nitrogen even at slow cooling rates. Recrystallized zones, therefore, are not darkened in etching. Cold deformation figures according to Fry's etching method originate only in steels tending to magnetic aging, *i.e.*, in steels capable of segregating nitrogen. Cold deformation figures are independent of the process of mechancial aging. GN(25)

Diffraction of Electrons and the Investigation of the Adsorption of Gases. (Eine Anwendung der Elektronenbeugung auf die Untersuchung der Gasadorption.) L. H. Germer *Zeitschrift für Physik*, Vol. 54 (1929), pages 408–421.

Under suitable experimental conditions, four different diffraction diagrams can be obtained when a beam of electrons falls, at suitable velocity on a single crystal of nickel. One of these is attributed to the space lattice of the metal, a second to the outside layer of metallic atoms, a third to a thick gas layer and the last to a gas layer only one atom thick. The thin gas layer has its atoms arranged in a kind of two-dimensional "gas crystal" and the distribution between neighboring atoms in the outside layer of the crystal. A diagram is given by Germer illustrating the probable relative positions of the gas atoms and the nickel atoms in the two adjoining surface layers. The observations made appear to indicate that the surface in which the centers of the adsorbed gas atoms lie is about 3.0 A. U. from that in which the centers of the outside layer of metal atoms lie. The sensitivity of the new method toward adsorbed gases is due to the fact that the electrons do not penetrate into the crystal as easily as the X-rays.

(25)

The Determination of Gases in Metals, Especially Oxygen in Iron and Steel According to the Vacuum Extraction Method. Part III. Oxygen in Cast Iron. (Zur Bestimmung der Gase in Metallen, besonders des Sauerstoffs in Eisen und Stahl, nach dem Heissextraktionsverfahren. III. Teil: Sauerstoff im Gusseisen.) H. DIERGARTEN & PIWOWARSKY. *Archiv für Eisenhüttenwesen*, Vol. 3, April 1930, pages 627–635.

Report No. 73 of the Chemists Committee of the Verein deutscher Eisenhüttenleute. The publication deals with the known literature on oxygen in cast iron and gives results of the Committee's own tests. Two groups of tests were made with Swedish charcoal iron of the composition C 3.66%, Si 0.10%, Mn 0.17%, P 0.074%, S 0.0085%. Increasing amounts of oxygen between 0.0054–0.0074% were added in the form of iron oxide to the melts made in a high frequency furnace. The first group, including five melts with increasing oxygen, was introduced into the bath (1420° C.) and unchanged casting temperature (1360° C.). The second group includes two subdivisions (oxygen increasing on a small and large scale respectively) with increasing oxygen content but decreasing temperature of adding oxygen and decreasing casting temperature. Oxygen in all melts was determined by the vacuum extraction method. The physical properties of the melts and the influence of the added oxygen on the chemical analysis and the structure of cast iron was tested. The values of oxygen in common cast iron ranges between 0.002% and 0.014%. A remarkable influence of oxygen on the physical properties of hot molten cast iron cannot be expected. A theoretical explanation of the oxygen content in cast iron is given. For practice the conclusion is drawn that scrap and other media containing oxygen can be added to cast iron melts without impairing the physical properties provided high temperatures are applied and the time of reaction is sufficient. Castings tending to porosity and formation of blowholes generally contain higher amounts of oxygen. GN(25)

The Hydrogen and Carbon Monoxide Contents of Some Metals Melted in a Vacuum. (Sur la teneur en hydrogéne et en oxyde de carbone de quelques métaux fondus dans le vide.) A. VILLACHON & G. CHAUDRON. *Comptes Rendus*, Vol. 189, Aug. 12, 1929, pages 324–326.

Metals are melted in a vacuum of about 1/50 mm. at 1700°, or 1/500 mm. at 1000°, in Mg crucibles that have previously been heated at a very high temperature. When the ingots obtained are made into leaflets 1/10-mm. thick, and heated at temperature below the melting point they still evolve H_2 and CO, but no N_2. After all the gas possible is evolved at a given temperature, raising the temperature makes it possible to remove still more gas. Fe, Ni, Cu and Al gave this result. (25)

INSPECTION (26)

Practical Aspects of Spark Testing. WALTER G. HILDORF & C. H. MCCOLLAM. *Engineer*, Vol. 149, Feb. 21, 1930, pages 220–221.

Reprinted from *Iron Age*, Oct. 10, 1929, pages 953–956. See *Metals & Alloys*, May 1930, Vol. 1, page 528. LM(26)

Equipment for Determining Thickness of Chromium Plate. *Brass World*, April 1930, Vol. 26, pages 94–95.

The General Testing Laboratories, Inc., Detroit, Mich., market a chromium thickness test outfit. It consists of 6 solutions marked 5, 10, 15, 20, 25 and 30 millionths, respectively, in referring to plating thickness and covering the range of decorative chromium plating. An area of definite size is isolated on the object by using a rubber gasket (an assortment of which is provided with the set) and applying a grease to one side of the gasket which is then placed on the object. The solution corresponding to the minimum specification for the work is used together with the reacting solution. A definite color change takes place, the solution changing from black to colorless. If the plate is less than the specified thickness no color change occurs and the spot remains black. Actual thickness is then determined by comparative tests with the standard solutions.

WHB(26)

Material Testing in the Manufacture of Steel for Ball-bearings. (Om materialkontrol vidtilverkning av kulbagerstal.) JOEL LARSSON. *Jernkontorets Annaler*, Jan. 15, 1930, Vol. 114, pages 27–42.

The main requirements of steel for ball-bearings are the following: (1) it must be as free from slag inclusions and other inhomogeneities, which tend to make the material shatter in use, (2) it must be free of surface imperfections, porosity, cracks, etc., (3) it must have no carbonization on the surface, (4) it must be uniformly annealed. While it is pointed out that no general rules can be laid down for carrying out control tests, and that it is impossible to test every piece of material produced, the tests may nevertheless serve to detect errors in the manufacturing processes. Thus in one factory it was shown that porosity does not increase with the cross section of the rods, but is dependent on the decrease of area on the finished cold-rolled product. It was also shown that two furnaces gave much larger percentages of slag inclusions because a larger quantity of coal was used in the generators for these furnaces, while two other furnaces gave fewer slag inclusions because less sulphur went into the charge as a result of using less coal in the producer. HCD(26)

Specifications and Materials Control. H. A. BACKUS. *Preprint* 33c, *Symposium on Aircraft Materials*, June 1930 Meeting, *American Society for Testing Materials*, 10 pages.

General discussion. Also lists tests to be applied for identification and uniformity. Every steel bar, tube or sheet should be individually inspected and tested by the user, for aircraft purposes. HWG(26)

EFFECTS OF ELEMENTS ON METALS & ALLOYS (27)

Chromium as an Alloying Element in Steel. M. A. GROSSMAN. *Transactions American Society for Steel Treating*, Vol. XVI, July 1929, pages 165–170.

A summary of the applications of chromium as an alloying element in steel includes reference to the long-established popularity of the nickel-chromium constructional steels in the automotive industry and to the important application of chromium in corrosion- and heat-resisting steels of a complex type. Reference is made to steels of this class in which a large percentage of nickel is an essential feature, *i. e.*, steels containing (1) nickel 8, chromium 18%, (2) nickel 20 or 23, chromium 7%. (27)

Practical Hints in Non-Ferrous Casting. A. HOPWOOD. *Foundry Trade Journal*, Vol. 41, Aug. 15, 1929, pages 112–114.

Reference is made to the improvement effected in copper alloys by the addition of small amounts of nickel, a concrete example of which is afforded by an alloy containing copper 87, nickel 3.25, tin 3.75, zinc 5, lead 1%. This alloy, which has mechanical properties approximately equivalent to those of Admiralty gun metal (copper-tin-zinc alloy) is easier to machine and shows better corrosion resistance and high temperature properties than the alloy containing no nickel. (27)

Nickel Cast Iron in Commercial Transport. *Nickel Bulletin*, Vol. 2, Dec. 1929, pages 181–185.

By adding nickel and chromium in ratio of about 3 to 1, wear-resistance is improved. By changing the ratios various conditions may be met. Gives results of experimentation with numerous combinations.

MLM(27)

Action of the Principal Addition Elements in Steel. L. PERSOZ. *Foundry Trade Journal*, Vol. 40, Mar. 7, 1929, pages 181–182.

Discusses in detail the effect in steel of the following elements: N, P, As, S, Mn, Cr, Ni, Cu, W, V, Mo, U, Co, Ti, Al, B and Ce. The amounts of each that should be present in steel are given as well as the effects of excess amounts. VSP(27)

Book Reviews

The Tariff on Iron and Steel. By ABRAHAM BERGLUND & PHILIP G. WRIGHT. The Brookings Institution, Washington, D. C., 1929. Cloth $5^{1}/_{2} \times 7\ ^{1}/_{2}$ inches, 240 pages. Price, $3.00.

The authors conclude from their investigation that the tariff favored the development on the iron and steel industry in earlier decades, and now that the industry is on a solid foundation so far as tonnage products are concerned, it has served its purpose. In the opinion of the authors, value of the tariff is questionable in view of the extremely favorable production and marketing conditions. The duties on tonnage products could, therefore, be removed without appreciable injury to producers, and with benefit to the construction industry and other users. The plants located near the Atlantic seaboard should either close their plants or improve the efficiency. The duties on molybdenum ores, ferro-molybdenum, ferro-vanadium and tungsten and manganese ores are designated as superfluous.

Only in the case of high carbon steels, certain alloy steels as well as ferrochrome, ferro-tungsten and ferro-silicon produced in the electric furnace, is the necessity for tariff protection recognized. The duties on these products though should only provide sufficient protection to equalize our competitive position.—R. R.

Engineering Materials. Vol. 1—Ferrous. By ARTHUR W. JUDGE. Isaac Pitmann & Sons, New York, 1930. Cloth, $6 \times 8^{1}/_{2}$ inches, 683 pages, 233 figs. Price, $8.50.

In this revision of "Aircraft and Automobile Materials," the author has followed the scheme of his earlier book, to produce a book which will prove useful to users of steel as an index to existing materials and information concerning them. It is inevitable that in a book of this character, the author could not hope to collect, classify and present in some sort of order even the more important information for those concerned with the application of engineering materials—they will, therefore, find it necessary to look further for the more detailed information.

A serious defect of the book is the manner in which the metallography of iron and steel is treated. In the attempt to give a brief account of the rather complex metallography of steel, the author has made many decided confusing and misleading statements, one of which is Fig. 20 appearing over the title "Equilibrium Curves for Iron-Carbon." The author should have adhered to his intention, stated in the preface, of confining himself to the properties of materials, which are of direct concern to the user. This would have been a means of keeping down the size of the book, as in that case the first chapter of the book could have been omitted. The reviewer can only advise readers who find the balance of the book useful, to ignore the first 50 pages.

In many instances the author has dealt in some detail with one typical material of a certain group, freely using trade-marked names of steels and alloys and of the data on them published by the manufacturers. For example, in the case of the tungsten-carbide-cobalt cutting compounds, he speaks only of "Carboloy," no mention being made of "Widia" or of the other compounds of the same nature.

Further, it is unfortunate that in discussing the nitrogen-hardening process, the author uses the term "nitration process." "Nitration" has a perfectly definite chemical significance, referring to processes involving the formation of a nitrate. No such compound is formed in the nitrogen-hardening process, in which the compounds formed must be of nature of nitrides, so that the process would more properly be termed a "nitriding process."

Most of the references used by the author were naturally British; it was a considerable surprise to the reviewer that while some reference is made to the results obtained in this country, only three French references appear in the footnotes and the German literature seems to have been ignored altogether.

The defects pointed out above do not detract from the general value of the book as a guide to ferrous materials. The author quotes the British Engineering Standard Specifications for many of the materials. In many instances, also, he gives actual test data with typical analyses. These are useful in view of a tendency, which undoubtedly exists, to regard specifications as typical of what may be expected of a material.—R. RIMBACH.

Modern Refractory Practice, with Special Reference to the Products of Harbison-Walker Refractories Company. Published by the Company, Pittsburgh, 1929. Half Cloth, $8 \times 11^{1}/_{2}$ inches, 178 pages.

The first 84 pages of the book illustrate the mining of the raw materials, as well as the manufacture of the finished product. The following kinds of brick are considered: fireclay, high-alumina, silica, magnesite, chrome and acid-proof. Complete information is given on standard sizes and shapes.

The book goes far beyond the conventional catalogue, as it contains in the last hundred pages information of interest to all users of refractories, in compact, usuable form. A section is devoted to the application of the refractories in furnace construction in the blast furnace, boiler furnace, by-product ovens, ceramic kilns, cupolas, electric furnaces for iron and steel, the gas plant, glass furnaces, heating furnaces, malleable iron furnaces, open hearths, cement kilns, etc.

Tables show how to calculate the brick required for arches of any span and rise, these have never before appeared in print. The glossary and the large amount of general information makes this book of practical helpfulness to refractories users.—R. R.

Patents, Trademarks, Copyrights—Law and Practice. By OSCAR A. GEIER. Richards & Geier, New York, 1930, Fifth Edition. Cloth, 6×9 inches, 128 pages. Free on application to publishers.

This fifth edition has been completely revised and brought up-to-date to conform with the changes of the law and practice since the fourth edition was issued in August 1928.

The book is written in terms the business man can understand, and covers the essential features of our Patent, Trademark and Copyright Laws.

The Patent Law section of the book explains who may obtain a patent, what may be patented, the importance of specification and claims, patent interferences, reissues, appeals, infringements suits, etc.

The Trademark end of the book covers trademarks in general, valid trademarks, invalid trademarks, unfair competition, state registration, interferences, oppositions, appeals, infringements, etc.

In addition to facts about American patents and trademarks, this book also gives a large amount of information about the foreign patents and trademarks which will be of particular interest to manufacturers who export. The index, with which it concludes, affords ready reference to the many important subjects treated in this book.—R. R.

The Condensed Chemical Dictionary. Compiled and edited by the Editorial Staff of the Engineering Catalog Company. F. M. TURNER, editor. 2nd edition, completely revised and enlarged under supervision of T.C. GREGORY, editor, and ISABELLE M. WELCH, assistant editor. Chemical Catalog Company, New York, 1930. Cloth, $6^{1}/_{4} \times 9^{1}/_{2}$ inches, 451 pages. Price, $10.00.

The editors of the Condensed Chemical Dictionary, Second edition have brought together a great many facts in a manner usable to the laymen as well as to the technical man. The natural inaccuracies and omissions of the older edition have evidently been thoroughly corrected. The new edition has included a great many new headings and more information in the same bulk by using smaller type.

This work should be useful to the engineerig and technical organizations as a quick reference on chemical properties, methods of manufacture, grades, transportation and uses of chemical substances. The new headings include useful descriptions of such common materials as "varnish," "galvanized iron" and "soap" as well as a complete range of common and unusual chemicals. It should be valuable as an introduction and guide to more detailed study of special chemical problems and in many cases furnishes quite complete information where detail is unnecessary.

The writers have found this dictionary useful as a reference in special chemical fields outside their own experience. Judging by the data given on their own fields of experience the user need be little afraid of being misled by assuming accuracy in the facts given.

R. J. MCKAY AND H. E. SEARLE.

Merck's Index. An Encyclopedia for the Chemist, Pharmacist and Physician. Merck & Co., Inc. Published by the Company, Rahway, N. J., Fourth Edition, 1930. Cloth, $6 \times 9^{1}/_{2}$ inches, 600 pages. Price, $5.00.

The first edition of this index appeared in 1889 and it is over two decades since the appearance of the third edition. The work has been most thoroughly revised and improved, and its scope very much enlarged. Some tests included in former editions have had to make way for newer and more important material. Supplementary tables and tests have been added.

The book gives the names of chemicals, their synonyms; source, origin or mode of manufacture; chemical formulas and molecular weights; physical characteristics; melting and boiling points; solubilities; specific gravities; medicinal action; therapeutic uses; ordinary and maximum doses; incompatibilities; antidotes; special cautions; hints on keeping and handling, etc.

An appendix contains: reactions of the more important alkaloids and glucosides; characteristic reactions of acids, bases, metals and salts; a table of atomic weights; specific gravity tables; thermometric and metric conversion tables; and abbreviations.

Superficial examination would indicate that it deals only with chemicals although it is in no sense restricted to Merck products. It therefore covers much of the ground already covered by Hackh's very excellent "Chemical Dictionary."—R. R.

The Construction and Equipment of Chemical Laboratories. Report of the National Research Council Committee. The Chemical Foundation, Inc., New York, 1930. Cloth, 340 pages, 124 figs. Price, $1.00.

This book fills a great need as a source of information in cases where the construction of a laboratory is under consideration. The aim of the Committee was to prepare a book which would be an aid to chemists in preparing preliminary plans for new laboratories or the improvement of those already built, to furnish architects and engineers with dependable information of the specific needs of chemical laboratories, and to discuss critically the various materials available for their construction and equipment. It is pointed out in the foreword that "necessarily, only general rules or suggestions can be put forward by the Committee as the planning of every laboratory constitutes a problem which must be solved locally in each case........"

The whole subject of university laboratory construction is excellently treated and should furnish many ideas and sufficient authoritative information to anyone contemplating laboratory construction. It is regretable that the report deals primarily with educational laboratories. Chapter XIX deals with industrial chemical laboratories, but this chapter only considers a few industrial research laboratories.

It is hoped that future issues will cover the needs of the industrial laboratory more fully. It is also suggested that more attention be given to the preparation to the half-tone illustrations in future issues.

An index of dealers in laboratory equipment and apparatus is issued with the book as a supplement, but it is pointed out that no effort was made to make this complete. For details of the various apparatus and equipment the reader is referred to the classified lists of advertisers in *Industrial & Engineering Chemistry, Chemical & Metallurgical Engineering* and the *Chemical Engineering Catalog*. The reviewer would add to this the "Buyers' Guide" of "Instruments".—R. R.

Lectures on Steel and Its Treatment. JOHN F. KELLER. American Society for Steel Treating, Cleveland. Second Edition, 1930. Cloth, 6×9 inches, 329 pages, 214 figs. Price, $3.50.

The book includes a series of seven lectures, which are in part the result of many years of intensive study of the properties of iron and steel. These cover in detail: the melting of steel and working the ingot; mechanical working of iron and steel; the iron-carbon diagram, annealing and cast iron; determination of critical points and physical testing; hardening, quenching, tempering and carburizing; warping, cracking and shrinking of steel; alloy steel, cast steel and welding.

According to the author, he has made an effort to present the subject matter in easily understandable form. As the author served his apprenticeship as a blacksmith, he understands the shortcomings of the previous texts for a better understanding of the subject by "practical men." The individual lectures, which in part are a result of a long and energetic study of the author, contain considerable valuable information, without going into long theoretical discussions. The many illustrations also give very valuable information.

The book will offer much to the beginner, but offers nothing new to the practical or college trained metallurgist.—RICHARD RIMBACH.

Die Werkstoffdämpfung bei Drehschwingungen nach dem Dauerprüfverfahren und dem Ausschwingverfahren. By W. Knackstedt, Wöhler Institute. N. E. M. Verlag, Berlin, 1930. Paper, 60 pages, 29 figures. Price, 5 R. M.

Three methods of determining the tendency toward absorption of energy by inelastic action are described. In the static method, a torsion specimen is deformed by a known torque, the deformation measured optically, and the hysteresis loops obtained on loading and unloading to equal positive and negative values.

In the continuous method, the specimen is repeatedly twisted back and forth through the same angle, at a definite speed, and the rise of temperature of the specimen due to inelastic action and absorption of energy is measured.

In the "dying-out" method, the specimen is made the stem of a torsional pendulum, and allowed to trace a logarithmic decrement curve.

Machines at the Wöhler Institute for the application of all three methods, the mathematics involved, and the precautions and corrections required, are all described in detail.

Proportional damping curves are given for copper, brass, duralumin, Lautal, elektron, Rübel bronze, structural steel, copper-chromium steel and ball bearing steel, but the composition, condition and heat-treatment of the materials are not given.

While these methods for the study of the damping phenomena are obviously being worked on in reference to their bearing on endurance testing, no comparison of the results is made with those of endurance tests. The pamphlet deals almost exclusively with the theory and practice of test methods.—H. W. Gillett.

Edelguss. Eine Sammlung Einschlägiger Arbeiten. Edited by G. Meyersberg. Julius Springer, Berlin, 1929. Second edition. Paper, $6 \times 9^{1}/_{4}$ inches, 170 pages, 129 figs. Price, 11.00 R. M.

The first edition of this book appeared in 1927 under the name "Perlitguss." This present edition, as also the previous one, was prepared with the object of furnishing information to engineers, machine designers, purchasers of castings, etc., on the production possibilities, physical properties and advantages of high test cast iron. The book assembles a number of carefully chosen articles from the literature and society reports appearing in the last 10 years on high test cast iron and allied subjects.

A brief introduction giving information on the structure of cast iron would have made the book more valuable to the readers to which it should appeal, as the average engineer or machine designer does not have sufficient knowledge of metallography to follow and clearly understand the individual articles.—Richard Rimbach.

Metall-und Legierungskunde. By M. von Schwarz. Ferdinand Enke, Stuttgart, Germany, 1929. Cloth, $7^{3}/_{4} \times 10^{3}/_{4}$ inches, 383 pages, 337 figs. Price, 29 R. M.

The book of M. von Schwarz is a reference book in non-ferrous metals and alloys. Considering the wide field of the subject we cannot expect to find a complete record on all non-ferrous metals.

The author deals with his subject in three principal chapters. A general outline on the principles of non-ferrous metallurgy and on the properties of metals and alloys of this group is given in the first 150 pages. The next 100 pages consider individually and in detail non-ferrous metals and alloys. On the last 100 pages an alphabetical index of the most important alloys and of all those which are in practical use is tabulated.

Considered as a reference book the last two chapters can be regarded as being more valuable for the average metallurgist, the more so as the outline of the general principles in the first chapter cannot be considered complete and up-to-date.—G. Neuendorff.

Mitteilungen der Deutschen Materialprüfungsanstalten. Sonderheft X. Arbeiten aus dem Kaiser Wilhelm-Institut für Metallforschung & Staatlichen Materialprüfungsamt zu Berlin-Dahlem. Verlag Julius Springer, Berlin, 1930. Paper, 8×12 inches, 142 pages, 327 figs. Price, 23 R. M.

Eighteen reports are collected in this volume. In many cases these reports have already appeared as articles in various periodicals, which are abstrated by Metals & Alloys. Below the titles of the reports are given and in the case of those covered by Metals & Alloys, the issue and page on which the abstract appears is given.

Bauer, O., & Zunker, P. Einfluss der Temperatur und der Abkühlungsverhältnisse beim Giessen von Zink.

Schmid, E. Gefügeuntersuchungen an gegossenen Metallen und Legierungen (Nov. 1929, page 245).

Hansen, M. Die Löslichkeit von Kupfer in Silber (Sept. 1929, page 118) A translation of this appears in Metals & Alloys, Nov. 1929, pages 248–250.

v. Göler & Sachs, G. Die Veredelung einer Aluminiumlegierung im Röntgenbild (Dec. 1929, page 285).

Sachs, G. Schmiedespannungen, Vergütungsspannungen und Wärmespannungen (July 1929, page 28).

Bauer, O., & Arndt, H. Der Einfluss des Einwalzens von Rohren auf gewöhnliches Kesselblech und auf Izett-Blech.

Kuntze, W., Sachs, G. & Sieglerschmidt, H. Elastizität, statische Versuche und Dauerprüfung.

Sachs, G. & Stenzel, W. Die Dehnung von Blechen (Oct. 1929, page 179).

Sachs, G. & Sieglerschmidt, H. Prüfung von Seildrähten durch Zug- und Biegeversuche (Aug. 1929, page 78).

Nix, F. C. & Schmid, E. Ueber die Gusstextur von Metallen und Legierungen (Mar. 1930, page 427).

v. Göler & Sachs, G. Walz- und Rekristallisationstextur regulär-flächenzentrierter Metalle (Mar. 1930, page 427).

Polanyi, M. & Schmid, E. Zur Frage der Plastizität. Verformung bei tiefen Temperaturen.

Boas, W. & Schmid, E. Bemerkungen zur Kristallplastizität.

v. Göler & Sachs, G. Zugversuche an Kristallen aus Kupfer und α-Messing (Sept. 1929, page 118).

Masima, M. & Sachs, G. Wärmeeffetke bei der Dehnung von Messingkristallen (Mar. 1930, page 427).

Boas, W. & Schmid, E. Ueber die Temperaturabhängigkeit der kritischen Schubspannung von Kadmiumkristallen.

Schmid, E. & Vaupel, O. Festigkeit und Plastizität von Steinsalzkristallen.

Bauer, O. & Deiss, E., Zur Probenahme und Analyse von Rotguss und anderen zur Seigerung neigenden Legierungen.

Werkstoffnormen—Stahl, Eisen, Nichteisen-Metalle. Deutscher Normenausschuss. Beuth-Verlag, Berlin, July, 1929, 4th Edition. Paper, $6 \times 8^{1}/_{4}$ inches, 140 pages. Price, 3.50 R. M.

Standard specifications for physical testing, steel and iron, rolled steel, drawn steel, non-ferrous metals, electric wire, etc.—R. R.

Reviews of Manufacturers' Literature

In this department we shall list each month a selection of the catalogs, books, treatises and other printed matter issued by manufacturers which, in our judgment should be of interest to the readers of Metals & Alloys. *Unless otherwise noted, any of the items listed may be secured free upon application to the issuing firm. Manufacturers who have not yet sent in their printed matter for consideration by the editor of this department are invited to do so, and it is suggested that* Metals & Alloys *be placed on the regular mailing list so that advance copies of any material of interest to the metallurgical field may automatically come to this department*—Editor.

Heat Treatment.—The 1930 issue of Catalog 90 "The Hump Method for Heat Treatment of Steel" is similar to the last edition except that it contains on pages 10 and 11 a presentation of the problem of control of the rate of heating above the critical with the same precision as below it. The discussion of this problem is followed on pages 15, 16 and 17 with an outline of its solution through the use of Leeds & Northrup automatic rate control as applied to the Hump method of hardening. Leeds & Northrup Company, 4901 Stenton Ave., Philadelphia, Pa.

Foundry Melting in Electric Furnace.—Nielson Survey PE-20-AK reports on the advantages obtained with the application of a Moore 'Lectromelt furnace to the manufacture of intricate steel castings by the Eastern Steel Castings. Copies of the survey can be obtained from The Pittsburgh Electric Furnace Co., Pittsburgh, Pa.

Automatic Controllers for Temperature.—A series of leaflets illustrates the application of L & N controllers to heat treatment in railway shops, to blast furnace production and to galvanizing. Leeds & Northrup Company, 4901 Stenton Ave., Philadelphia, Pa.

Pneumatic Flotation Machine.—Bulletin No. 5 includes general arrangement drawings of the Geco Pneumatic Flotation Machine (MacIntosh Type) as well as information pertaining to the particular features of this machine. Special instructions for care and operation are also included. 22 pages. The General Engineering Company, Inc., 50 Broad St., New York, New York.

Metal Testing Machinery.—An 88 page booklet illustrates and describes tensile, compression, impact, torsion, bending and hardness testing machines. Catalogue No. 390. H. Z. Schniewind, 72 Duane St., New York, New York.

Welding.—2 new pamphlets issued as a part of the Linde Process Service are: "Outline Training Course for Aircraft Welders"—an outline of instructions based on procedure control; and "Production Welding"—illustrates and describes the application of the oxy-acetylene process as a production method in a number of the more important industries. Linde Air Products Company, 205 East 42nd St., New York, N. Y.

New Welding Electrodes.—Leaflet covers the Flex-Arc Welding Electrodes. This is a general purpose steel-welding electrode evolved by extensive experimental and development work conducted in actual welding practice. It contains several illustrations showing these electrodes and their applications. Leaflet 20479. Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa.

Direct Current Motors.—Bulletin GEA—1924 contains information on the Type MPC Direct-Current Motors for moderate or heavy duty. General Electric Company, Schenectady, New York.

Air Separators.—A 6-page bulletin shows construction of Federal Separators. Bulletin No. 5. Federal Pneumatic Systems, Inc., 125 North Dearborn St., Chicago, Ill.

Mine and Industrial Locomotives.—Special Publication 1873 contains a photograph, a drawing and data covering the performance and the electrical and mechanical construction of each of 17 mine locomotives and 7 industrial locomotives. 28 page bulletin Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa.

Oil Electric Locomotives.—60-page booklet containing a description of the applications, operation and construction of oil electric traction apparatus. Special publication 1880. Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa.

Manganese Steel.—The Amsco Bulletin, August 1930, Vol. 2, No. 8, describes a number of applications of manganese steel. 8 pages. American Manganese Steel Company, 389 East 14th Street, Chicago Heights, Ill.

Architectural Aluminum.—4 page folder illustrates the applications of aluminum for architectural use. Apex Smelting Company, 2554 Fillmore Street, Chicago, Ill.

Facts for Foundrymen.—A 48-page booklet giving some facts and technical data relating to various metals and alloys supplied by the Niagara Falls Smelting & Refining Corp., 2204 Elmwood Avenue, Buffalo, New York.

Thwing Thermo-Electric Pyrometers.—Fully described and illustrated with illustrations of a few typical installations in their 24-page Bulletin 10. Thwing Instrument Company, 3339 Lancaster Avenue, Philadelphia, Pa.

Kromepatch "Stands the Gaff."—A 4-page advertising broadside. E. J. Lavino and Company, Bullitt Building, Philadelphia, Pa.

The Udylite News.—A monthly bulletin issued by the Udylite Process Company, 3220 Bellevue Avenue, Detroit, Michigan, the July issue of which contains the story of Udylite in connection with cadmium plating.

Automatic Temperature Control Equipment.—Reduced size reprint of complete catalogue L3 showing full line of instruments with chart scales and other pertinent data. Wilson-Maeulen Company, 383 Concord Avenue, New York.

High Temperature Cement.—Hytempite, a refractory cement for boiler settings, metallurgical furnaces and other industrial furnaces, is discussed in a recent 8-page bulletin. Methods of applying the product, both in new construction and in making repairs, are mentioned. Quigley Furnace Specialties Co., 26 Cortland St., New York, N. Y.

Plating Equipment.—A new catalog, 128 pages, with index, goes very thoroughly into the subject of electroplating equipment, including polishing and buffing supplies for the operations preceding the plating. Formulas for electroplating baths and other useful information are included. Hanson-VanWinkle-Munning Co., Matawan, N. J.

The Plating of Rolled Zinc and Zinc Base Die Castings.—A 12-page illustrated bulletin assembling, in as complete and concise form as possible, the information necessary for the practical plating of rolled zinc and die cast zinc parts. The New Jersey Zinc Co., 160 Front St., New York.

Manufacture of Nickel Steel Plate.—A reprint from the Transactions of the American Society of Mechanical Engineers. It deals with the manufacture, rolling and inspection of steels containing 2 and 3% nickel and which is used in boiler construction, and particularly with the manufacture of fairly large plates from $^{1}/_{4}$–$^{1}/_{2}$ inch in thickness. 8 pages. Nickel Steel Data No. 14. International Nickel Co., Inc., 67 Wall St., New York, N. Y. Other publications of the same company: Buyers' Guide, Nickel Alloy Steel Products, Jan. 1, 1930.

Steel Castings.—Leaflet illustrates the application of steel castings to the manufacture of high pressure valves. Lebanon Steel Foundry, Lebanon, Pa.

Patent Department

Through an arrangement with Mr. W. M. Corse, Metallurgical Engineer, Washington, D. C., who operates a well-known Patent Information Service, we are able to publish every month a list of important patents in the metallurgical field from the United States, Canada and Europe. The following countries will be included in the European listing: England, Germany, France, Switzerland, Denmark, Norway, Sweden and Italy.

If our readers wish more information about any of the patents listed below they can get it by writing to our Patent Department, and mentioning the fact that they have the reference in METALS & ALLOYS. *We will be prepared to mail copies of United States Patents to clients within twenty-four hours of date of issue by special arrangement. Photostatic copies, translations of claims and of full text of foreign patents will be supplied if desired.*

This service is furnished under special arrangement with Mr. Corse's organization at most reasonable rates. Full information can be secured by writing to Patent Department, METALS & ALLOYS, *419 Fourth Avenue, New York.*

United States Patents

Subject of Invention, Patentee, Patent No. and Filing Date.

Method of protecting metal-coating baths and composition therefor. E. R. Millring, assignor to American Machine & Foundry Co. Reissue No. 17,722. (Original No. 1,674,694 filed Jan. 9, 1925.) Mar. 8, 1930.

Process of refining (degasifying and deoxidizing) of copper. M. G. Corson. No. 1,769,986. Apr. 26, 1927, renewed Nov. 12, 1929.

Revolving-barrel sand-blast machine. E. A. Rich, assignor to The American Foundry Equipment Co. No. 1,770,013. Mar. 24, 1926.

Apparatus for measuring the hardness of materials. A. F. Shore and C. P. Shore, assignors to The Shore Instrument & Mfg. Co. No. 1,770,045. Mar. 16, 1925, renewed Oct. 4, 1929.

Apparatus for measuring the hardness of materials. A. F. Shore, assignor to The Shore Instrument Co. No. 1,770,046. Apr. 4, 1925.

Heat-treating furnace. P. W. McCoy and J. A. Masury, assignors to The Surface Combustion Co., Inc. No. 1,770,081. Dec. 21, 1928.

Furnace. F. A. Fahrenwald. No. 1,770,103. Jan. 18, 1927, renewed Jan. 23, 1929.

Cutting element. (Chromium-edged razor blade.) C. H. Humphries. No. 1,770,157. June 23, 1927.

Production of coated metallic objects. E. D. Martin. No. 1,770,177. Sept. 4, 1925; in France Sept. 8, 1924.

Pipe and method of making it. J. C. Mitchell, assignor to Lock Joint Pipe Co. No. 1,770,180. Mar. 18, 1926.

Die for making journal box wedges. W. G. Powell. No. 1,770,323. Oct. 28, 1927.

Mold. E. G. Fahlman, assignor to The Permold Co. No. 1,770,368. Apr. 18, 1929.

Process of desulphurizing ferrous metal. H. L. Frevert. No. 1,770,395. Feb. 24, 1928.

Alloy. W. R. Saltrick, assignor to Robert Wickersham Stimson. No. 1,770,433. Feb. 14, 1923; in Great Britain Mar. 7, 1922.

Manufacture of steel alloys. H. C. Bigge and P. G. Paris, assignors to Bethlehem Steel Company. No. 1,770,508. Jan. 6, 1925.

Spot welding of brass and aluminum. E. Lunn, assignor to Pullman Car & Manufacturing Corporation. No. 1,770,540. Mar. 1, 1929.

Bushing. (Cu-Fe-Pb lined with Cu-Pb.) R. D. Pike, assignor to Kalif Corp. No. 1,770,582. July 9, 1928.

Welding machine. W. J. Kirkman. No. 1,770,649. Feb. 23, 1926.

Induction Furnace. E. F. Russ. No. 1,770,662. May 24, 1928; in Germany Aug. 21, 1926.

Mold and facing therefor. C. C. De Witt. No. 1,770,684. Apr. 8, 1929.

Molding sand and material for treating same. C. C. De Witt. No. 1,770,685. Apr. 8, 1929.

Synthetic molding material and method of forming same. C. C. De Witt. No. 1,770,686 and No. 1,770,687. Apr. 8, 1929.

Molding material. C. C. De Witt. No. 1,770,688. Apr. 8, 1929.

Method of pickling alloys. L. L. Satler, assignor to Allegheny Steel Co. No. 1,770,712. Nov. 25, 1927.

Process for treating manganese ores and the like. G. N. Libby and G. E. Knight, assignors to Emory Winship. No. 1,770,791. Apr. 12, 1926.

Arc-welding electrode and process of making the same. P. O. Noble and J. A. Capp, assignors to General Electric Co. No. 1,770,799. Apr. 15, 1927.

Electrode for arc welding and process of making the same. E. W. Schwartz and F. R. Kaimer, assignors to General Electric Co. No. 1,770,811. Jan. 15, 1927.

Arc-welding apparatus. J. Sauer, assignor to General Electric Co. No. 1,770,808. Sept. 6, 1927; in Germany Sept. 21, 1926.

Art of protectively treating metals. A. Arent, assignor to Arthur Arent Laboratories, Inc. No. 1,770,828. Dec. 8, 1925.

Electric Contact. C. F. Carpenter, assignor to General Electric Co. No. 1,770,839. Nov. 1, 1926. (Cd plated.)

Cast-metal pipe and method of making the same. D. H. Meloche, assignor to American Radiator Co. No. 1,770,858. May 17, 1928.

Treatment of nickeliferous material. S. C. Smith. No. 1,770,866. Apr. 18, 1929; in Great Britain Apr. 18, 1928.

Electrolyzer. L. U. La Corsa. No. 1,770,789. May 3, 1929; in Italy June 9, 1928.

Continuous bar-heat-treating furnace. F. T. Cope, assignor to The Electric Furnace Co. No. 1,770,842. May 8, 1928.

Oven lining. W. J. Laffrey, assignor to Central Alloy Steel Corp. No. 1,770,930. Mar. 18, 1926.

Method of manufacturing chemically-pure aluminum by electrolysis. K. L. Meissner. No. 1,770,940. Aug. 1, 1927; in Germany Dec. 2, 1926.

Machine for and process of forming metal into shapes. C. M. Yoder. No. 1,770,963. May 24, 1926.

Method of making die blocks for forging turbine blades. R. C. Allen, assignor to Westinghouse Electric and Manufacturing Co. No. 1,770,964. Apr. 30, 1929. (Second division of original filed Dec. 3, 1924.)

Rotary-hearth furnace. O. A. Colby, assignor to Westinghouse Electric & Manufacturing Co. No. 1,770,970. Dec. 7, 1928.

Art of rolling sheet metal. A. Paterson. No. 1,770,993. Oct. 6, 1927.

Method of corrugating metal boiler sheets. C. E. Bronson and J. F. Dickson, assignors to Kewanee Boiler Corp. No. 1,771,028. Dec. 31, 1928.

Valve member. (Tin-silver alloy.) W. S. Ireland, assignor to National Refrigeration Corp. No. 1,771,043. Apr. 28, 1926.

Ingot type-metal mold. M. G. Bachmann. No. 1,771,110. Apr. 25, 1929.

Ladle. (Heated by high-frequency current.) A. Fry, assignor to F. Krupp A. G. No. 1,771,114. May 3, 1929; in Germany May 18, 1928.

Greensand core. W. S. Anderson. No. 1,771,201. Nov. 25, 1925.

Hot-metal mixer. L. E. Allen, assignor to Pennsylvania Engineering Works. No. 1,771,241. Aug. 8, 1929. (Division of original filed June 16, 1928.)

Checkerwork construction. C. W. Andrews, *et al*, assignors to H. A. Brassert & Co. No. 1,771,282. July 13, 1929.

Checkerwork. A. J. Hulse and C. W. Andrews, assignors to H. A. Brassert & Co. No. 1,771,286. Jan. 18, 1928.

Checkerbrick and checkerwork construction. A. J. Hulse, assignor to H. A. Brassert & Co. No. 1,771,298. Aug. 20, 1928.

Flue structure for regenerative stoves. A. C. Nelson. No. 1,771,306. Aug. 10, 1928.

Soldering torch. G. E. Jubb and E. B. Libby. No. 1,771,334. Mar. 23, 1929.

Apparatus for making turbine blades. R. C. Allen, assignor to Westinghouse Electric & Manufacturing Co. No. 1,771,368. June 14, 1927. (Division of original filed Dec. 3, 1924.)

Method of coating wire (with metal). C. D. Johnson, assignor to Johnson Steel & Wire Co., Inc. No. 1,771,379. May 31, 1929.

Continuous strip and sheet mill. W. M. Blecker. No. 1,771,392. Aug. 16, 1927.

Method of rolling tubes from hollow blocks. M. Roeckner, assignor to the Firm of Vereinigte Stahlwerke Akt.-Ges. No. 1,771,420. Feb. 6, 1928; in Germany Feb. 25, 1927.

Method of alumino-thermic welding. J. Wattmann. No. 1,771,472. Sept. 20, 1929; in Germany Oct. 16, 1928.

Cutting torch. G. C. Quelch, assignor to International Oxygen Co. No. 1,771,511. Aug. 23, 1926.

Optical pyrometer. C. E. Foster. No. 1,771,533. Nov. 6, 1926; in Great Britain Nov. 19, 1925.

Process of converting hafnium and zirconium salts. J. H. de Boer, assignor to N. V. Philips' Gloeilampenfabrieken. No. 1,771,557. Oct. 18, 1924; in the Netherlands Nov. 15, 1923.

Porous bearing body. J. Brincil. No. 1,771,615. Apr. 11, 1928.

Process of forming compound metal bodies. F. Ehrmann, assignor to Robert Bosch Akt.-Ges. No. 1,771,620. Feb. 11, 1927; in Germany Apr. 19, 1926.

Apparatus for electroplating. S. Ishisaka. No. 1,771,680. Mar. 29, 1927.

Method and apparatus for manufacturing metal sheets from ingots. R. D. Nye. No. 1,771,688. Jan. 26, 1927.

Driving mechanism for rolling-mill wedges. A. L. Ellis, assignor to The Waterbury Tool Co. No. 1,771,750. July 6, 1929.

Revolving-ring hearth oven. L. Honigmann and F. Bartling. No. 1,771,756. June 2, 1926; in Germany June 3, 1925.

Unoxidizable alloy. (Ni-Cu-Mn-Sb-Sn.) C. Contal. No. 1,771,773. July 17, 1929; in France June 21, 1929.

Roller-bearing axle box. W. Jüregensmeyer, assignor to AB. Svenska Kullagerfabriken. No. 1,771,792. Oct. 6, 1928; in Germany Oct. 21, 1926.

Rolling-mill bearing. E. M. Jones and C. A. Writer, assignors of one-third to The Falcon Bronze Co. No. 1,771,791. Mar. 14, 1928.

Heat-treating furnace. J. Lundborg, assignor to The Surface Combustion Co. No. 1,771,853. Oct. 31, 1928.

Hardness-testing apparatus. F. Mohr. No. 1,771,858. Aug. 6, 1926; in Germany Nov. 12, 1925.

White-metal alloy. H. J. R. Overall. No. 1,771,899. Apr. 28, 1928; in Australia Nov. 10, 1927.

Process of protecting surfaces of aluminum or aluminum alloys. G. D. Bengough and J. M. Stuart. No. 1,771,910. July 28, 1924; in Great Britain Aug. 2, 1923.

Heating metal melts. A. Fry, assignor to Fried. Krupp Akt.-Ges. No. 1,771,918. May 3, 1929; in Germany May 18, 1928.

Electric furnace. C. Steenstrup, assignor to General Electric Co. No. 1,771,942. July 7, 1927.

Method of uniting thick metal parts by electric welding. C. L. Ipsen, assignor to General Electric Co. No. 1,771,961. Oct. 16, 1928.

Typographical casting machine. D. S. Kennedy, assignor to Mergenthaler Linotype Co. No. 1,771,962. Dec. 22, 1928.

Machine for handling molding sand. W. E. Naylor, assignor to The Beardsley & Piper Co. No. 1,771,966. Feb. 11, 1927.

Process for the reduction of iron ores. W. E. Trent, assignor to The Trent Process Corp. No. 1,771,971. June 16, 1928.

Reduction of oxide ores. W. E. Trent, assignor to Trent Process Co. No. 1,771,972. May 8, 1929.

Process of coating bodies with tungsten. J. A. M. Van Liempt, assignor N. V. Philips' Gloeilampenfabriken. No. 1,771,974. Dec. 2, 1924; in the Netherlands June 28, 1924.

Wear-resisting current-carrying contact. H. Blomberg, assignor to General Electric Co. No. 1,771,977. Apr. 24, 1928; in Germany May 6, 1927.

Apparatus and method for recovering precious metals. J. E. Hopkins, assignor to The Nascent Amalgam Corp. Reissue No. 17,757. Jan. 2, 1930. (Original No. 1,678,142, filed June 21, 1926.)

Metal-bar-heating furnace. H. Bangert. No. 1,772,065. Feb. 11, 1928; in Germany Feb. 28, 1927.

Method of producing galvanic coatings. (Chromium-plating hollow bodies.) V. Engelhardt and K Illig, assignors to Siemens & Halske A.G. No. 1,772,074. Feb. 9, 1926; in Germany Oct. 17, 1925.

Method of making pistons. R. R. Grant. No. 1,772,215. July 18, 1923.

Rolling mill. C. J. Gibbons. No. 1,772,248. Aug. 3, 1927.

Process for tinning and cleaning soldering irons. C. F. Hamilton. No. 1,772,283. Jan. 23, 1928.

Furnace wall. J. C. Hobbs. No. 1,772,350. Jan. 8, 1926.

Method of forming integrally-joined sheets of dissimilar metals (for bearings). W. H. Klocke, assignor to Cleveland Graphite Bronze Co. No. 1,772,354 and No. 1,772,355. Sept. 6, 1927.

Apparatus and method for forging and roughing out iron and steel bars by electricity. E. Giacchino, assignor to Soc. Holding des Brevets et Procédés Giacchino pour l'Ebauchage Electrique, S.A. No. 1,772,444. Oct. 10, 1927; in Italy Nov. 9, 1926.

Austrian Patents

Subject of Invention, Patentee, Patent No. and Date of Beginning of Term of Patent.

Rolling mill accessory for stripping metal tubing from the mandrel. Imperial Chemical Industries, Ltd. No. 118,570. Mar. 15, 1930.

Electric annealing furnace for automatic operation. A. G. Brown, Boveri & Cie. No. 118,593. Mar. 15, 1930.

Method of casting steel and apparatus for mechanical treatment of the castings. F. Hammer. No. 118,605. Mar. 15, 1930.

Process for making amalgams. Deutsche Gold- und Silber-Scheideanstalt vorm. Roessler. No. 118,746. Mar. 15, 1930.

Process for reducing zinciferous material. The New Jersey Zinc Co. No. 118,590. Mar. 15, 1930.

Process for the preparation of fine-grained zinciferous material for dead-roast sintering. Comp. des Métaux Overpelt-Lommel S.A. No. 118,597. Mar. 15, 1930.

Process for working up alloys or residues containing antimony and copper. P. Kemp. No. 118,601. Mar. 15, 1930.

Process for roasting and reducing ores in the form of dust. R. Jahn. No. 118,819. Mar. 15, 1930.

Magnetic iron-nickel alloys. International Standard Electric Corp. No. 118,584 and No. 118,588. Mar. 15, 1930.

Process and furnace for obtaining mixed tin or lead-free or low-lead bearing metals from alloys of lead and tin which also contain other metals, particularly antimony and copper. Hüttenwerke Tempelhof A. Meyer. No. 118,816. May 15, 1928.

High-frequency induction furnace. Siemens & Halske A.G., assignee of V. Engelhardt. No. 118,589. Mar. 15, 1930.

Deep mounting for holders of closed electric furnaces. I. G. Farbenindustrie A.G. No. 118,806. May 15, 1930.

Process for making electrolytic iron. E. Kelsen, assignee of F. Halla. No. 118,818. Mar. 15, 1930.

Electrode rod having a plurality of mutually insulated electrode elements for electric arc welding or cutting. La Soudure Autogéne Française. No. 118,558. Mar. 15, 1930.

Machine for soldering the longitudinal seams of tin cans and the like by means of a soldering iron connected to the secondary of a transformer. Elektrische Löt- und Schweiss Ges. m. b. H. No. 118,582. Mar. 15, 1930.

British Patents

Note: Names of communicators, if any, are given in parentheses after the name of the applicant. When the date applied for differs from the date on which the application was lodged at the British Patent Office, the former date is given followed by *.

Subject of Invention, Patentee, Patent No. and Filing Date.

Process and arrangement for manufacturing a soldered or brazed joint. J. Schmitt and Victoria-Werke A.G. No. 330,885. Dec. 12, 1928.

Apparatus for the heat treatment of metalliferous materials. E.M.S. Industrial Processes, Ltd., *et al.* No. 330,930. Dec. 20, 1928.

Production of sound ingots. A. G. Egler. No. 303,157. Dec. 30, 1927.*

Structural metal work, comprising metal grids, etc., and the manufacture and installation thereof. C. W. Goodyear *et al.* No. 330,875. Jan. 9, 1929.

Lead alloy tanks. W. T. Butcher *et al.* No. 330,924. Mar. 18, 1929.

Manufacture of lead alloy products. W. T. Butcher *et al.* No. 330,925. Mar. 18, 1929.

Manufacture of lead yarn. W. T. Butcher *et al.* No. 330,960. Mar. 18, 1929.

Sand-packing devices for pipe molds. S. A. des Hauts-Fourneaux et Fonderies de Pont-á-Mousson. No. 310,510. Apr. 27, 1928.*

Apparatus for intercepting furnace dust in blast furnaces. J. Stoecker. No. 330,928. Mar. 19, 1929.

Method of and apparatus for producing a metallic spray. T. E. Bridger. No. 308,355. Mar. 22, 1928.*

Method of bonding sheets of dissimilar metals. J. V. O. Palm. No. 331,028. Apr. 26, 1929.

Process and apparatus for the production of pipe connections (fittings) of sheet metal. O. Reifruth. No. 331,038. Nov. 20, 1928.*

Furnace ladles. F. Krupp A.G. No. 312,064. May 18, 1928.*

Arrangement of laminated iron shells for current-carrying coils for induction furnaces. Allmänna Svenska Elektriska AB. No. 315,693. July 16, 1928.*

Method and machine for welding together radiator sections and the like. E. A. Rosengrens Kassaskaps-fabriks AB. No. 312,285. May 23, 1928.*

Internal galvanization of long hollow bodies. W. A. F. Pfanhauser. No. 331,104. July 1, 1929.

Uniting tubular and solid bars or like pieces of metal. C. Vouret. No. 331,107. July 5, 1929.

Process for manufacturing tools of homogeneous alloys of great hardness. G. Brewer. (F. Krupp A.G.) No. 331,121. July 25, 1929.

Manufacture or lining of pipes by centrifugal action. Hume Steel Ltd. and C. C. Halkyard. No. 331,143. Sept. 23, 1929.

Mechanism for the automatic disengaging of the clutch of the driving mechanism of drawing-drums on wire-drawing benches. C. Rasch. No. 331,144. Sept. 23, 1929.

Nozzle for delivering molding sand. W. Seidemann. No. 331,160. Oct. 23, 1928.*

Apparatus for upsetting sheet metal. H. Junkers. No. 331,175. (Addition to Nos. 238,537 and 256,962.) Dec. 18, 1928.*

Seamless tubes. Mannesmannröhren-Werke. No. 317,065. Aug. 10 1928.*

Metallization of thermally unstable substances, more particularly of organic electrically insulating substances. Siemens & Halske A.G. No. 306,902. Feb. 27, 1928.*

Coated metallic articles, particularly in electrical apparatus and machinery. J. Y. Johnson. (I.G. Farbenindustrie A.G.) No. 331,203. Mar. 18, 1929.

Production of pig iron. M. Neumark. No. 331,190. Mar. 22, 1929.

Apparatus for casting metals. United States Metals Refining Co. No. 308,689. Mar. 26, 1928.*

Core for making cast pipes. R. Ardelt. No. 331,288. Apr. 9, 1929.

Apparatus and process for the manufacture of lead-covered cables. Kabelfabrik A.G. No. 331,301. Feb. 7, 1929.*

Electrical induction furnaces. N. R. Davis and Associated Electrical Industries, Ltd. No. 331,324. May 8, 1929.

Method of producing malleable metal pipes. E. Weir. No. 317,720. Aug. 20, 1928.*

Melting and refining of copper. C. A. Jensen. (American Metal Co., Ltd.) No. 331,353. June 7, 1929.

Press for reforming tubes. American Fork & Hoe Co. No. 331,362. Oct. 24, 1928.*

Vertical hydraulic presses for metals. F. Krupp Grusonwerk A.G. No. 331,371. May 30, 1929.*

Lined metal crucibles. W. W. Triggs. (American Machine & Foundry Co.) No. 331,399. July 12, 1929.

Non-corrodible alloys of iron, and articles produced therefrom. K. M. Tigerschiold. No. 331,414. Aug. 2, 1929.

Alumino-thermic mixture and the like, and methods of obtaining the same. R. W. Hyde. No. 319,775. Sept. 29, 1928.*

Rolling metal sheets. W. Stringham. No. 331,448. Sept. 30, 1929.

Blast furnace tuyères and method of preventing the burning thereof. E. H. Holzworth. No. 331,464. Oct. 30, 1929.

Process and apparatus for expanding metal tubes. Mannesmannröhren-Werke. No. 331,476. Jan. 18, 1929.*

Apparatus for cleaning metal parts, particularly machine parts. J. J. V. Armstrong. (Hahn & Kolb). No. 331,479. Jan. 1, 1929.

Machine for hardening the bearing points of driving shafts. F. Klopp. No. 331,484. Feb. 25, 1929.

Electric furnaces. British Thomson-Houston Co., Ltd. No. 307,031. Mar. 1, 1928.*

Preparing silicon steel sheets for electrical purposes. A. F. Murphy and W. Jones. No. 331,511. Apr. 2, 1929.

Rolling railway track rails. C. Rötzel. No. 331,514. Nov. 22, 1928.*

Coating of metal bodies with metal. W. Baur. No. 331,550. Apr. 3, 1929.

Centrifugal casting of metal pipes. Soc. d'Expansion Technique. No. 310,047. Apr. 20, 1928.*

Dynamo-electric machines more especially for arc welding. Elin A.G. für elektrische Industrie. No. 312,357. May 25, 1928.*

Method of rust prevention in kettles made of tin plate. W. M. Simpson. No. 331,649. May 22, 1929.

Processes and casting molds for manufacturing zinc containers for gavanic elements, batteries or the like. No. 331,650. May 22, 1929.

Method of and apparatus for welding tubes. Youngstown Sheet & Tube Co. No. 316,964. Aug. 7, 1928.*

Process and machine for producing sand cores for use in casting metals. C. H. Taylor. No. 331,656. May 28, 1929.

Process for manufacturing spoons, forks and knife handles. A. Prinz. No. 316,671. Aug. 2, 1928.*

Gas-suction apparatus for mineral furnaces. E. Somoza. No. 317,727. Aug. 20, 1928.*

Foundry-mold handling equipments. C. Arnold. (Osborn Manufacturing Co.) No. 331,774. Oct. 2, 1929.

Soldering-apparatus. Elektrische Löt-und Schweiss-Ges. No. 331,776. Aug. 30, 1929.*

Method and apparatus for melting down easily fusible and easily oxidizable metals and alloys. C. Brackelsberg. No. 331,791. Aug. 20, 1929.*

Electric annealing furnace. Hirsch, Kupfer- & Messingwerk A.G. No. 331,793. Dec. 15, 1928.*

Production of metals and alloys by exothermic reduction. W. B. Hamilton and T. A. Evans. No. 331,892. Feb. 5, 1929.

Electrically driven rollers for rolling mills and like purposes. Demag A.G. No. 314,790. July 2, 1928.*

Preventing corrosion of metallic surfaces. H. Sutton *et al.* No. 331,853. Apr. 8, 1929.

Processes for the preparation of organic articles for electrolytically covering them with a metallic layer. No. 331,863. (Addition to No. 300,060.) I. Ainstein. Apr. 9, 1929.

Process and apparatus for the electrolysis of molten substances. I.G.Farbenindustrie A.G. No. 309,605. Apr. 14, 1928.*

Rolling mills. L. R. Michell. No. 312,066. May 19, 1928.*

Electrically welded metal tubing. H. F. McLoughlin. No. 331,998. May 27, 1929.

Electric furnaces. R. M. Catterson-Smith. No. 332,015. June 7, 1929.

Kilns or furnaces for the calcination, burning or roasting of limestone, iron-ore, etc. C. F. Priest. No. 332,037. June 25, 1929.

Flux for welding. W. Reuss. No. 332,048. (Addition to No. 296,923.) Nov. 1, 1928.*

Method of manufacturing profiled metal pieces, such as metal plates, strips or the like. H. Seiferth. No. 332,051. June 27, 1929.*

Manufacture and production of porous metal articles. J. Y. Johnson. (I.G. Farbenindustrie A.G.) No. 332,052. July 8, 1929.

Rolling mills. AB. Svenska Kullagerfabriken. No. 332,085. Oct. 23, 1928.*

Canadian Patents

Subject of Invention, Patentee, Patent No. and Filing Date.

Metallurgy of tin. C. G. Fink and C. L. Mantell. No. 301,545. July 25, 1927.

Production of iron alloys free from gases. C. Brackelsberg. No. 301,555. Feb. 8, 1929.

Rust proofing method. W. H. Cole. No. 301,559. Mar. 13, 1929.

Metallurgical furnace. E. Lund. No. 301,584. Sept. 7, 1929.

Lead refining process. The American Smelting and Refining Co., assignee of B. W. Gonser and C. W. Haffey. No. 301,629. Jan. 16, 1929.

Method of producing uranium and uranium-zinc alloys. The Canadian Westinghouse Co., Ltd., assignee of J. W. Marden. No. 301,646. Feb. 2, 1927.

Process of preparing zirconium. The Canadian Westinghouse Co., Ltd., assignee of W. P. Kiernan. No. 301,647. Apr. 30, 1927.

Furnace. The Canadian Westinghouse Co., Ltd., assignee of J. F. Baker. No. 301,648. May 20, 1927.

Induction furnace. The Canadian Westinghouse Co., Ltd., assignee of P. H. Brace. No. 301,649. July 28, 1927.

Furnace cycle control. The Canadian Westinghouse Co., Ltd., assignee of H. S. Gano. No. 301,650. Nov. 21, 1927.

Method of obtaining chromium. The Canadian Westinghouse Co., Ltd., assignee of M. N. Rich. No. 301,652. Mar. 31, 1928.

Method of treating metallic filaments. The Canadian Westinghouse Co., Ltd., assignee of J. H. Ramage. No. 301,653. Mar. 31, 1928.

Method of separating zirconium, titanium and hafnium. The Canadian Westinghouse Co., Ltd., assignee of M. N. Rich. No. 301,654. Mar. 31, 1928.

Protective coating for metal surfaces. The Canadian Westinghouse Co., Ltd., assignee of C. V. Iredell. No. 301,656. Nov. 9, 1928.

Terminal for resistance conductors. The Canadian Westinghouse Co., Ltd., assignee for W. R. King. No. 301,657. Aug. 12, 1929.

Method and material for preventing the tarnishing of silverware. The Pacific Mills, assignee of G. Jones. No. 301,723. July 23, 1929.

Process of surface plating of metals with alloys. The Research Corp., assignee of M. Fiedler. No. 301,732. Apr. 9, 1929.

Apparatus for treating hot galvanized articles. H. B. Newhall, assignee of C. A. Giblin. No. 301,755. Sept. 20, 1929.

Electrodeposition of iron. R. D. Pike, assignee of G. H. West and B. P. Little. No. 301,758. Oct. 1, 1928.

Metallurgical blast furnace. J. P. Dovel. No. 301,794. Aug. 24, 1927.

Grate for sintering apparatus. J. E. Greenawalt. No. 301,798. Dec. 13, 1928.

Process and apparatus for reducing iron oxide ore. W. W. Percy. No. 301,823. Oct. 18, 1928.

Extraction of lead. S. C. Smith. No. 301,830. June 29, 1926.

Method of making buttwelded tubes. C. M. Thomson. No. 301,833. Apr. 10, 1928.

Apparatus for removing gases from molten light metals, such as aluminum. W. Todt. No. 301,835. July 29, 1929.

Method of making lined bearings. The Cleveland Graphite Bronze Co., assignee of W. H. Klocke. No. 301,876. Oct. 24, 1928.

Welding apparatus. Thermweld Ltd., assignee of A. D. Ross. No. 301,887. Nov. 22, 1928.

Hollow drill steel. Fagersta Bruks AB., assignee of O. A. E. Gumaelius. No. 301,891. Dec. 12, 1928.

Apparatus for operating cupolas. The Griffin Wheel Co., assignee of F. K. Vial and G. S. Evans. No. 301,901. Sept. 17, 1928.

Method of preparing mercury for the separation of minerals from ores. The Mineral Recovery Process (of Canada) Ltd., assignee of R. Luckenback. No. 301,918. Nov. 1, 1928.

Metal casting apparatus. The McCord Radiator & Mfg. Co. No. 301,921. Sept. 9, 1929.

Process of treating iron ores. The Sulphide Corp., assignee of E. W. Westcott. No. 301,944. May 14, 1928.

Grate for sintering apparatus. J. E. Greenawalt, assignee of T. M. Alexovits. No. 301,972. Dec. 13, 1928.

Recovery of precious metals by amalgamation. D. Enzlin and J. A. Eklund. No. 301,986. Sept. 1, 1928.

Aluminum-beryllium alloy. Aluminium Ltd., assignee of R. S. Archer and W. L. Fink. No. 302,055. Dec. 20, 1928.

Welding apparatus. The Bendix Brake Co., assignee of S. Whitworth. No. 302,067. Aug. 22, 1928.

Welding apparatus. The Bendix Brake Co., assignee of L. E. Long. No. 302,068. Aug. 22, 1928.

Magnesium-covered calcium wire. The Canadian General Electric Co., Ltd., assignee of W. A. Ruggles. No. 302,076. Sept. 21, 1926.

Process of smelting ores (of elements of group having atomic weights between 50 and 55). The Electro Metallurgical Co. of Canada, Ltd., assignee of F. M. Becket. No. 302,100. Mar. 30, 1929.

Silver extraction. Thomas Roberts & Co., assignee of E. Haehre. No. 302,141. Feb. 15, 1928.

Electric furnace. La Société Electrométallurgique de Montricher, assignee of P. L. J. Miguet. No. 302,146. Dec. 27, 1927.

Process and apparatus for producing rolled steel tubes. The Superheater Co., assignee of R. M. Swartz. No. 302,151. Jan. 10, 1929.

Air toughened alloy steel (Manganese steel). The Taylor-Wharton Iron and Steel Co., assignee of J. H. Hall and J. S. Comerford. No. 302,154. Sept. 27, 1929.

Process for producing metals from their oxide ores. The Trent Process Corp., assignee of W. E. Trent. No. 302,163. Feb. 25, 1929.

Apparatus for producing metals from their oxide ores. The Trent Process Corp., assignee of W. E. Trent. No. 302,164. Feb. 25, 1929.

Molding apparatus for ingot molds. (Sand ramming equipment.) The Valley Mould and Iron Corp., assignee of J. E. Perry and J. A. Lanigan. No. 302,169. July 17, 1928.

Combined electrode and stirring device. J. J. Naugle, assignee of S. A. W. Okell. No. 302,182. July 17, 1928.

Supporting finger for annealing furnaces. (For supporting conveyors.) F. A. Fahrenwald. No. 302,188. Feb. 7, 1929.

Method of reducing refractory metal oxides (such as those of V, Th, Cr, etc.). The Canadian Westinghouse Co., Ltd., assignee of M. N. Rich. No. 302,191. Mar. 31, 1928.

Feeding mechanism for metal-treating machines. The Copperized Steel, Ltd., assignee of A. F. Clarke. No. 302,301. Aug. 29, 1927.

Production of metal films. The Copperized Steel, Ltd., assignee of W. E. Watkins. No. 302,302. Oct. 7, 1929.

Brazing rod. (Cu-Zn-P.) The Dominion Oxygen Co., Ltd., assignee of A. R. Lytle. No. 302,308. Dec. 24, 1928.

Alloy. (Ni-Mo-Fe.) The Electro Metallurgical Co. of Canada, Ltd., assignee of F. M. Becket. No. 302,309. Feb. 15, 1929.

Process of smelting tungsten ores. The Electro Metallurgical Co. of Canada, Ltd., assignee of F. M. Becket and W. C. Read. No. 302,310. Feb. 28, 1929.

Covered weldrod for electric arc welding. The A. O. Smith Corp., assignee of R. Stresau. No. 302,366 and No. 302,367 Nov. 22, 1929.

Metallurgical process and apparatus. La Soc. "Le Nickel" S.A. assignee of C. Thurneyssen. No. 302,369. Feb. 21, 1927.

Apparatus for coating pipes, bars, etc. The U. S. Galvanizing & Plating Equipment Corp., assignee of K. T. Pothoff. No. 302,379. Dec. 2, 1929.

Autogenous welding of magnesium and its alloys. H. O. Berg, assignee of G. Michel. No. 302,288. Sept. 17, 1928.

Method of making steel. The Granular Iron Co., assignee of J. K. Smith. No. 302,393. Sept. 24, 1929.

Method of selectively controlling metal pickling baths. J. H. Gravell and A. Douty. No. 302,397. Mar. 10, 1928.

Titanium steel. W. and H. Mathesius. No. 302,398. Apr. 2, 1929.

Method and apparatus for casting molten metal under pressure. R. H. V. Christensen. No. 302,419. Feb. 14, 1929.

Process of preparing aluminothermic mixtures. R. W. Hyde. No. 302,440. Sept. 27, 1929.

Process of obtaining metallic lead. G. L. Oldright. No. 302,463. Nov. 18, 1927.

Aluminum-silicon alloy. H. Schorn. No. 302,479. Feb. 24, 1928.

Molding machine. J. D. Storie. No. 302,488. Jan. 21, 1930.

Case-hardening composition. The American Cyanamide Co., assignee of E. C. Moffett. No. 302,499.

Process of recovering cadmium. The American Smelting & Refining Co., assignee of R. Teats. No. 302,502. Apr. 24, 1929.

Electrodeposition of metal (such as zinc or cadmium). The Consolidated Mining & Smelting Co. of Canada, Ltd., assignee of W. H. Hannay and F. E. Lee. No. 302,534. Feb. 4, 1929.

Drawing furnace. The Hudson Motor Car Co., assignee of R. Z. Hopkins, *et al.* No. 302,576. July 30, 1928.

Cyanide pot. The Hudson Motor Car Co., assignee of V. P. Rumely. No. 302,577. Jan. 14, 1929.

Rosin-core solder. The Kester Solder Co., assignee of P. C. Ripley. No. 302,585. May 20, 1929.

Method of cleaning metal surfaces. The American Chemical Paint Co., assignee of C. F. Dinley. Nos. 302,609 and 302,611. Sept. 21, 1929.

Preparation for removing foreign substances from metallic surfaces. Same patentee and assignee. No. 302,610. Sept. 21, 1929.

Pipe-casting machine. La S.A. des Hauts-Fourneaux et Fonderies de Pont-à-Mousson, assignee of L. L. Mathieu. No. 302,621. Nov. 19, 1929.

Method of making flanged shapes. W. C. Oberg. No. 302,653. Jan. 2, 1929.

Universal rolling mill. A. E. Soderberg and A. G. Dahlgren. No. 302,654. Jan. 2, 1929.

Danish Patents

Subject of Invention, Patentee, Patent No. and Filing Date.

Electric process for the production of very fine-grained metallic powder. Tréfileries et Laminoirs du Havre. No. 42,389. Oct. 22, 1928.

Chaplet. E. K. Fokjaer and A. E. A. Orland. No. 42,406. Aug. 10, 1929.

Chill for inclusion in castings. L. Föbus. No. 42,413. Oct. 28, 1929.

Process for making homogenous alloys of lead with alkali or alkaline-earth metals and molded objects made of such alloys. I.G.Farbenindustrie A.G. No. 42,438. Jan. 4, 1929.

Process for electroplating with cadmium in a cadmium bath containing an alkali cyanide. No. 42,483. Mar. 24, 1927.

French Patents

Subject of Invention, Patentee, Patent No. and Filing Date.

Process for heating metals and other electrically-conducting materials for the purpose of melting or welding them or for other purposes. S. E. Koustnetsov. No. 689,165. Jan. 31, 1930.

Process for making aluminum-base casting alloys. A.G. der Eisen und Stahlwerke vormals Georg Fischer and Messingwerk Schwarzwald A.G. No. 689,206. Jan. 31, 1930.

Apparatus for roasting and sintering ores. A. Dawans. No. 689,324. Feb. 3, 1930.

Two-piece pouring spout for open-hearth furnaces. H. Moll and Rasselsteiner Eisenwerks A.G. No. 689,335. Feb. 3, 1930.

Improvements to metallurgical furnaces. A. Stansfield. No. 689,345. Feb. 3, 1930.

Process for agglomerating blast furnace dust. Rochlingsche Eisen und Stahlwerke A.G. No. 689,363. Feb. 3, 1930.

Process for effecting endothermic operations. Fried. Krupp Grusonwerk A.G. No. 689,456. Feb. 5, 1930.

Process for making sponge iron. Fried. Krupp A.G., Friedrich Alfred Hütte. No. 689,457. Feb. 5, 1930.

Alloy of iron and titanium. W. Kroll. No. 689,556. Feb. 7, 1930.

Process for making pure aluminum or light aluminum alloys for wire or cables having high mechanical strength and high electrical conductivity. Y Hanco. No. 689,593. Feb. 7, 1930.

Electric resistance furnace for heat treating metals and other substances. V. Sorrel and L. A. Lafont. Addition No. 36,999. (First addition to No. 641,635 filed Sept. 29, 1927.) June 3, 1929.

Aluminothermic welding process. Elektro-Thermit G.m.b.H. No. 689,248. Feb. 1, 1930.

Improvements to processes and apparatus for welding. Budd Wheel Co. No. 689,308. Jan. 14, 1930.

Improvements in the heat treatment of strips for making razor blades. Durham Duplex Razor Co. No. 689,310. Jan. 14, 1930.

Machine for cleaning sheets. P. Damiron. No. 689,389. Feb. 4, 1930.

Method of rolling. K. Nolte. No. 689,395. Feb. 4, 1930.

Process for making tubing of any length in drawing presses. Hydraulik G.m.b.H., and O. Schlenstedt. No. 689,511. Feb. 6, 1930.

Electro-pneumatic machine for making tubing. A. Descours. No. 689,544. Feb. 7, 1930.

Press for making lead-sheathed cables. Hydraulik G.m.b.H. No. 689,565. Feb. 7, 1930.

Improvements to processes for making finned tubing. Soc Alsacienne de Constructions Mécaniques. Addition No. 36,996. (First addition to No. 672,483 filed Apr. 4, 1929.) June 3, 1929.

Bath for removing chromium. Ternstedt Mfg. Co. No. 689,415. Feb. 4, 1930.

Automatic continuous mixer for foundry sand. A. Baillot. No. 689,973. Feb. 14, 1930.

Process for calcining basic fluxes (limestone or dolomite) in the blast furnace process. E. Baumgartner. No. 689,678. Feb. 10, 1930.

Process for melting metals in an ironless induction furnace. Hirsch, Kupfer und Messingwerke A.G. No. 689,754. Feb. 12, 1930.

Improvements in machines for stacking sheets. Tarentum Saving and Trust Co., *et al.* No. 689,812. Feb. 12, 1930.

Processes for improving rolled products. H. Weigel. No. 689,865. Feb. 13, 1930.

Process for incorporating phosphorus in cast iron. Y. Le Monies de Sagazan, and Soc. Phosphates & Superphosphates de Tebaka. No. 689,895. Apr. 19, 1929.

Process for spot welding copper. Fried. Krupp A.G. No. 689,636. Feb. 8, 1930.

Method and improved apparatus for extracting castings from molds. W. Wood. No. 689,638. Feb. 8, 1930.

Method and improved apparatus for freeing and stripping castings from molds. W. Wood. No. 689,639. Feb. 8, 1930.

Process for drop-forging metals, particularly for the fabrication of brakes. Bendix Brake Co. No. 689,682. Feb. 10, 1930.

Improvements to welding machines. Cie. Française pour l'Exploitation des Procédés Thomson-Houston. No. 689,769. Jan. 3, 1930.

Process and machine for making billets for drawing. Les Tréfileries de Lisieux. No. 689,906. Apr. 22, 1929.

Improvements to machines for cleaning white iron sheets. J. H. Cole. No. 689,964. Feb. 14, 1930.

Electric shaft furnace for treating scrap metals as well as oxide and sulphide ores. No. 689,874. Feb. 14, 1930.

Continuously-operating electric resistance furnace for heating or for chemical reactions. L. Vennin. No. 689,955. Apr. 29, 1929.

Improvements to burners, torches and similar apparatus. Soc. L'Air Liquide (S.A. pout l'Etude et l'Exploitation des Procédés Georges Claude) No. 689,953. Apr. 27, 1929.

Improvements to processes for obtaining strips of material coated with metal foil. L. Rado. No. 689,838. Feb. 13, 1930.

Forging machine. C. Brunotte. No. 690,012. Feb. 14, 1930.

Process and apparatus for the reduction of zinciferous material containing lead. The New Jersey Zinc Co. No. 690,027. Feb. 15, 1930.

Improvements to rolling mills with crossed rolls. P. Bredsdorff Abramsen. No. 690,047. Feb. 15, 1930.

Device for permitting the rolling of two passes at the same time in opposite directions in the same stand. S. A. John Cockerill. No. 690,128. Feb. 17, 1930.

Process for preparing metals. I. G. Farbenindustrie A.G. No. 690,141. Feb. 18, 1930.

Process for rolling or drawing and machine for working this process. E. Bornand and H. A. Schlaepfer. No. 690,070. Feb. 15, 1930.

Process and apparatus for casting metals and other materials. Wetherill-Morris Engineering Co. No. 690,071. Feb. 15, 1930.

Improvements to welding machines, particularly machines for welding longitudinal seams. Cie Française pour l'Exploitation des Procédés Thomson-Houston. No. 690,152. Feb. 18, 1930.

Inductor windings for electric induction furnaces. Electric Furnace Co., Ltd. No. 689,999. Feb. 14, 1930.

Process for preventing surface decarburization in annealing or other heat treatment, particularly of steel. Fagersta Bruks AB. No. 690,203. Feb. 19, 1930.

Refining of copper. Electrical Research Products, Inc. No. 690,219. Feb. 19, 1930.

Process for reducing ores. A. Musso. No. 690,255. Dec. 23, 1929.

Process for making sheet steel coated with copper, nickel or an alloy of these metals. A. Anciaux. No. 690,345. Feb. 20, 1930.

Process for making pipe elbows having folds projecting into the interior thereof. Allgemeine Rohrleitung A.G. and Franz Seiffert & Co. No. 690,431. Feb. 22, 1930.

Process and apparatus for casting objects of brass, bronze, aluminum and other metals or alloys. A. Furrer and X. Bourgoin. No. 690,475. Feb. 24, 1930.

Means for the suspension in electric furnaces of heating resistances in the form of strips of chrome-nickel and similar alloys. E. F. Russ. No. 690,195. Feb. 19, 1930.

Improvements to electric induction furnaces. G. H. Clamer. No. 690,231. Feb. 19, 1930.

Process for preventing contamination of the atmosphere in electrolytic plants and materials used for this purpose. Anaconda Copper Mining Co. No. 690,437. Feb. 22, 1930.

Process and means for obtaining inert atmospheres. Westinghouse Electric & Manufacturing Co. Addition No. 37,091. (Second addition to No. 590,307, filed Dec. 11, 1924.) Mar. 28, 1929.

Process for improving titaniferous copper or copper alloys. W. Kroll and M. Lissauer & Cie. No. 690,503. Feb. 24, 1930.

Process for improving the mechanical properties, particularly the compressive strength of objects made of magnesium or magnesium alloys. I.G.Farbenindustrie A.G. No. 690,654. Feb. 25, 1930.

Apparatus for skimming off slag and similar materials. Det Norske A/S for Elektrokemisk Industri. No. 690,687. Feb. 26, 1930.

Process for the production of ferrochromium. K. M. Simpson. No. 690,692. Feb. 26, 1930.

Process for making self-hardening aluminum alloys. A.G. der Eisen & Stahlwerke vormals Georg Fischer and Messingwerk Schwarzwald A.G. No. 690,771. Feb. 27, 1930.

Process for making porous metallic objects. I.G.Farbenindustrie A.G. No. 690,485. Feb. 24, 1930.

Improvements to electric soldering irons. G. Jussigh. No. 690,703. Feb. 26, 1930.

Process for casting piston rings. T. E. McFall. No. 690,723. Feb. 26, 1930.

Mill for foundry sand. S.A. des Etablissements Bonvillain & E. Ronceray. No. 690,724. Feb. 26, 1930.

Process for forming coatings on metals. Dr. Otto Sprenger Patentverwertung Jirotka. Addition No. 37,112. (First addition to No. 655,786, filed Mar. 3, 1928.) June 19, 1929.

Improvements to electrolytically deposited protective coatings for tanks. W. S. Einstein. No. 690,631. Feb. 2, 1929.

Process for the extraction and treatment of metals and metalloids. Sindicato Maquepta. No. 690,608. May 3, 1929.

Process for effecting reactions between gases and solids and apparatus for working this process. Sulphur and Smelting Corp. No. 690,667. Feb. 25, 1930.

Process for making and improving copper alloys. P. M. G. Metal Trust, Ltd. No. 690,875. July 26, 1929.

Improvements in the production of ingots. Aluminium, Ltd. No. 690,914. Feb. 11, 1930.

Electric soldering iron whose temperature is controllable. B. J. J. Dupuy, No. 690,849. Mar. 1, 1930.

Method and means for operating a plurality of welding or cutting torches on a common source of gas. F. Mangiameli. No. 690,926. Feb. 19, 1930.

Process for producing finely divided metals from their carbonyl compounds. I.G.Farbenindustrie A.G. No. 690,991. Mar. 2, 1930.

Improvements to brazing torches. L. R. Pabion and G. Duchet. No. 691,008. Mar. 3, 1930.

Means for automatically turning and shifting the work in press or hammer forging. Vereinigte Stahlwerke A.G. No. 691,034. Mar. 3, 1930.

Improvements to electric arc welding generators. P. Boudier and J. Boudier. Addition No. 37,126. (First addition to No. 669,473, filed Feb. 11, 1929.) Feb. 20, 1929.

Improvements in the control of high temperatures, particularly the thermal control of certain operations, especially annealing. A. Kurpjuhn. No. 690,825. Feb. 28, 1930.

Galvanoplastic process and apparatus therefor. Major Engineering Co. No. 690,956. Feb. 28, 1930.

Improvements to machines for the electrolytic fabrication of sheets or tubing. E. Kelsen. Addition No. 37,141. (First addition to No. 648,580, filed Feb. 9, 1928.) June 24, 1929.

Process for making carbonyl compounds of metals. I.G.Farbenindustrie A.G. No. 691,100. Mar. 5, 1930.

Rotary furnace. R. P. E. Roman and T. Lafitte. No. 690,919. Feb. 17. 1930.

German Patents

Subject of Invention, Patentee, Patent No. and Filing Date.

Process for making seamless tubing. E. Alvermann. No. 502,155. Nov. 2, 1926.

Clamping device for machines for welding longitudinal seams in tubing or tubular objects. Mauser Maschinenbau G.m.b.H. No. 501,953. June 25, 1927.

Vertical extrusion press for making metal tubing with a plurality of pistons and mandrels. Hydraulik G.m.b.H. No. 502,426. Aug. 30, 1927.

Metal drawing tool. H. Spörl. No. 502,408. Apr. 13, 1929.

Tuyère for industrial furnaces. H. Rothe. No. 502,241. Oct. 6, 1928.

Burner for hot-blast stoves which are heated in alternation. Askania-Werke A.G. No. 502,243. Jan. 11, 1929 and No. 503,182. June 1, 1926.

Salt-bath crucible furnace. Siemens-Schuckertwerke A.G. No. 502,242. Nov. 1, 1928; in the United States Nov. 7, 1927.

Mounting heat elements in electric furnaces. E. F. Russ. No. 502,413. Mar. 9, 1926.

Process for electrically heating spring clips. Maschinenbau-Anstalt Moll A.G. No. 502,457. Mar. 12, 1927.

Means for arc welding with polyphase current. M. Zack. No. 502,318. Apr. 12, 1924.

Slag-separating dam between furnace and forehearth, which permits the observation of the melting operation in the furnace. H. Meixner. No. 501,942. Feb. 16, 1926.

Sand slinging machine. AB. Axel Christiernsson and AB. Eksjö Mekaniska Verkstad. No. 502,079. May 10, 1928; in Sweden May 5, 1927.

Sand-blowing machine for filling molds. E. Schlechte. No. 502,462. (Addition to No. 479,521.) July 25, 1928.

Process and machine for producing solid metal ingots by centrifugal casting. Mannesmannröhren-Werke. No. 502,080. June 16, 1928.

Process for making centrifugally cast pipe. G. Ostermann. No. 502,081. June 27, 1928.

Pattern element made of flexible material. E. Mengler. No. 502,082. Sept. 4, 1927.

Process for making castings under pressure. H. Barthel. No 502,321. Mar. 21, 1926.

Roasting furnace installation. Siegener A.G. für Eisenkonstruktion Brückenbau und Verzinkerei. No. 502,196. Dec. 25, 1927.

Roasting furnace for zinc blende. Balz-Erzröstung G.m.b.H. No. 502,322. (Addition to No. 419,308.) Jan. 8, 1927.

Operation of roasting and sintering furnaces. Soc. pour l'Enrichissement et l'Agglomeration des Minerais S.A. No. 502,469. Mar. 11, 1928.

Reduction of ores. H. Wittek. No. 502,197. (Addition to No. 487,560.) July 28, 1926.

Decomposing ores, chemical products and similar raw materials. H. J. L. Fleck. No. 502,095. June 6, 1926.

Recovery of bismuth, tin, antimony and similar volatile metals from sulphide ores by blowing. E. J. Kohlmeyer. No. 502,198. (Addition to No. 494,454.) Aug. 18, 1928.

Process for the electrolytic production of bright rust-proof coatings composed principally of zinc. Studien-Ges. für Wirtschaft und Industrie m.b.H. No. 501,947. Dec. 5, 1925.

Device for moving the electrodes of electrolytic baths back and forth. R. Blasberg. No. 502,113. Dec. 28, 1927.

Process for plating metal. Copperized Steel, Ltd. No. 502,114. July 19, 1927; in the United States Dec. 24, 1926.

Continuous, electrically-driven roll train. Heraeus Vacuumschmelze A.G. and W. Rohn. No. 502,766. Jan. 7, 1927.

Device for transferring rolled bars from a cooling bed to a roller conveyer bed. Morgan Construction Co. No. 502,789. Jan 7, 1927.

Process for making wrought iron pipe connections. W. Geldbach. No. 503,196. June 20, 1929.

Process for making objects composed of two parts of different thickness, for example for American plowshares. Lintorfer Walzwerk und Vertriebs G.m.b.H. No. 502,791. June 30, 1927.

Method of charging electric melting furnaces having a removable roof. Demag A.G. No. 503,010. June 18, 1927.

Cover with deflector ring, for pot annealing furnaces. F. Rieke. No. 503,035. Nov. 18, 1928.

Coreless induction melting furnace. Ajax Electrothermic Corp. No. 502,691. Nov. 24, 1925; in the United States Nov. 29, 1924.

Apparatus for manual arc welding. Allgemeine Elektricitäts Gesellschaft. No. 503,162. Nov. 2, 1926.

Vertical furnace. R. G. Neumann. No. 503,224. Oct. 1, 1929.

Sand-blowing machine, with movable nozzle, for filling molds. Badische Maschinenfabrik und Eisengiesserei. No. 503,225. Dec. 13, 1928.

Compressed-air conveying device, particularly for molding sand. Same patentee. No. 503,226. Jan. 9, 1929.

Portable molding machine. Maschinen- und Werkzeugfabrik, Kabel, Vogel & Schemmann A.G. No. 503,227. Nov. 28, 1929.

Process for making composite castings, using separating walls. W. Alberts and F. Stein. No. 502,933. Aug. 29, 1929.

Process for making composite ingots. K. Nolte. No. 502,934. Dec. 28, 1928.

Device connected with the ladle of centrifugal casting machines for indicating the amount of metal poured. S.A. des Hauts-Fourneaux et Fonderies de Pont-à-Mousson. No. 502,824. Sept. 12, 1928; in France Apr. 27, 1928.

Longitudinally divided die-casting mold. Maschinenfabrik Adolf Viebahn. No. 502,935. Feb. 3, 1929.

Roasting sulphide ores, particularly zinc blende, in two steps. Metallges. A.G. No. 502,586. June 5, 1929.

Separating multi-component alloys. O. Naeser. No. 502,832. Oct. 21, 1926.

De-zincing liquid slags by blowing. W. Buddeus. No. 502,587. Oct. 18, 1929.

Separation of mechanically-mixed metals. Metallges. A.G. No. 502,833. Dec. 25, 1928.

Process for the production of magnesium chloride by fusion electrolysis. M. N. Lacell. No. 503,014. Dec. 12, 1926; in France Mar. 26, 1926.

Process for the electrolytic extraction of heavy metals from sulphides or mixtures of oxides and sulphides. H. Skappel. No. 502,954. Feb. 26, 1924; in Norway Feb. 26, 1923.

Means for testing the welds of iron vacuum tubes for large rectifiers. A. G. Brown, Boveri & Cie. No. 502,590. Oct. 18, 1928.

Process for the production of silver-plated metal objects, for example, tableware. M. H. Wilkens & Söhne A.G. No. 502,532. Dec. 12, 1928.

Machine for upsetting electrically-heated objects. L. Renault. No. 502,977. July 27, 1928; in France Jan. 7, 1928.

Operation of several constant-pressure welding burners from the same oxygen and acetylene lines. F. Mangiameli. No. 502,724. (Addition to No. 489,788.) Oct. 5, 1929.

Process for soldering lead or lead alloys. The Expanded Metal Co., Ltd. No. 502,978. Feb. 12, 1929.

Process for finishing and for the final sizing of tubular bodies of porous metal. Bound Brook Oilless Bearing Co. No. 502,849. Sept. 5, 1926.

Means for changing, cooling and dressing the mandrels of pilger rolling mills. Witkowitzer Bergbau-und Eisenhütten-Gewerkschaft and L. Tschulenk. No. 503,477. Apr. 13, 1927.

Machine and method for hardening the head of railroad rails suspended head downward. Eisenwerk-Ges. Maximilianshütte. No. 503,369. Feb. 24, 1926.

Electric furnace installation for continuous operation. A. G. Brown, Boveri & Cie. No. 503,725. Feb. 21, 1926.

Conveyer furnace. Allgemeine Elektricitäts Gesellschaft. No. 503,370. May 13, 1928.

Electric induction furnace. Hirsch, Kupfer und Messingwerke A.G. No. 503,614. July 25, 1928.

Hydraulic or pneumatic clamping device, particularly for electric welding machines. Allgemeine Elektricitäs Gesellschaft. No. 503,401. Aug. 31, 1927; in the United States Aug. 30, 1926.

Process for electrically welding high-carbon ferrous parts to low-carbon iron. R. Samesreuther. No. 503,350. Jan. 8, 1927.

Electrode for electric resistance welding and soldering. Simson & Co. No. 503,402. Nov. 15, 1928.

Process for melting copper and apparatus for working the same. Hirsch, Kupfer und Messingwerke A.G. No. 503,529. Aug. 31, 1928.

Sand slinging machine for preparing molding sand. G. Oetzbach. No. 503,629. Feb. 11, 1928.

Machine for making metal pipes by centrifugal casting. Soc. d'Expansion Technique. No. 503,576. Nov. 11, 1927; in France Nov. 10 and Nov. 17, 1926.

Treatment of fine-grained materials. H. M. Ridge. No. 503,431. Dec. 18, 1928.

Smelting zinc ores. The New Jersey Zinc Co. No. 503,432. July 26, 1927; in the United States Apr. 1, 1927.

Optical pyrometer. R. Hase. No. 503,243. Apr. 12, 1928.

Electrolytic chromium-plating process. Langbein-Pfanhauser-Werke A.G. No. 503,353. Jan. 9, 1929; in France Jan. 12, 1928.

Method of and means for heating tunnel furnaces. N. Lengersdorff. No. 503,355. Jan. 30, 1924.

Rotary furnace with more than two annular tracks. Fried. Krupp Grusonwerk A.G. No. 503,328. June 8, 1929.

Rotary tubular furnace. G. Polysius A.G. No. 503,464. May 17, 1925.

Electrically-driven conveyor roller, particularly for roller beds of rolling mills. Siemens-Schuckertwerke A.G. No. 504,339. Jan. 27, 1928.

Shock-absorber for presses for drawing sheet metal. Press Cushion Co. No. 504,212. Sept. 12, 1928.

Process and mill for rolling boiler tubes. G. Burkhardt. No. 504,495. (Addition to No. 453,124.) Aug. 25, 1927.

Process for making welded pipe connections. H. Seelbach. No. 504,213. Jan. 22, 1929.

Disk-rolling mill with one or more rolls. Budd Wheel Co. No. 504,111. Apr. 10, 1925.

Rolling mill for making balls. Eisen- und Stahlwerk Hoesch A.G. No. 504,112. July 18, 1928.

Process for working up titanium ores containing chromium, with recovery of the sulphuric acid. Deutsche Gasglühlicht-Auer-Ges. m.b.H. No. 504,500. Apr. 15, 1928.

Blast furnace with protective jacket surrounding the brickwork. Broken Hill Proprietary Co., Ltd. No. 504,399. Dec. 9, 1927; in Australia Dec. 9, 1926.

Suspended roof for melting furnaces, particularly open-hearth furnaces. G. Karrenberg and H. Römer. No. 504,415. Nov. 10, 1926.

Process for making objects of spring steel, having good elastic properties and with a bright surface. Stahlwerk Becker A.G. and W. Oertel. No. 504,400. Oct. 1, 1927.

Electric salt-bath crucible furnace. Siemens-Schuckertwerke A.G. No. 504,000. (Addition to No. 502,242.) Feb. 5, 1929; in the United States Feb. 14, 1928.

System of supplying power to induction furnaces. Siemens-Schuckertwerke A.G. No. 504,126. Oct. 31, 1926.

Electric melting furnace for aluminum, zinc, tin and the like. E. F. Russ. No. 504,419. Feb. 2, 1929.

Sand-retaining edge of sheet iron. R. Fritzsch. No. 504,255. May 17, 1928.

Device for inserting and withdrawing the bell cores of centrifugal pipe casting machines. Halbergerhütte G.m.b.H. No. 504,420. Oct. 5, 1926.

Valve for a die-casting machine. Berliner Maschinenbau A.G. vormals L. Schwartzkopff. No. 504,413. June 11, 1926.

Pouring machine with several ladles for filling molds with a plurality of gates. Buderus'sche Eisenwerke. No. 503,843. June 11, 1929.

Extraction of zinc from oxidic ores. Metallges. A.G. No. 504,227. Oct. 14, 1927.

Separation of cobalt from nickel. Allgemeine Elektro-Metallurgische Ges. m.b.H. No. 504,437. Dec. 28, 1928.

Process for extracting metals which form volatile compounds with sulphur, particularly tin, bismuth and molybdenum. Guggenheim Bros. No. 503,806. May 24, 1925; in the United States June 7, 1924.

Electrolytic process for the production of a particularly resistant chromium plating. Siemens & Halske A.G. No. 503,866. Mar. 19, 1927.

Process for making chromium anodes. E. Maas. No. 503,807. Dec. 22, 1927.

Process for repairing worn rolls, particularly blooming rolls by welding metal on the worn places. A. Münten. No. 504,334. July 14, 1928.

Plugs for closing the preheating channel of molds for aluminothermic welding. H. Schultz. No. 504,276. Feb. 4, 1930.

Process for making hard bodies for tools, particularly drawing dies, out of carbides, silicides, borides, aluminum oxide or mixtures of these. O. Diener. No. 504,484. Feb. 13, 1926.

Electric drive system for rolling mills. Siemens-Schuckertwerke A.G. No. 504,680. Nov. 4, 1928; in the United States Nov. 19, 1927.

Process for stiffening sheet metal. Metallindustrie Mettmann J. Klefisch. No. 504,540. Sept. 8, 1929.

Means for conveying pierced, substantially flat objects to a rolling mill. Budd Wheel Co. No. 505,021. May 14, 1925; in the United States Apr. 9, 1925.

Thread-rolling machine. Gebr. Hilgeland. No. 504,874. Feb. 24, 1927.

Chain-conveyor annealing furnace for annealing pipes. "Ilva" Alti Forni & Acciaierie d'Italia. No. 504,864. Nov. 26, 1927.

Method of piling objects for heat treatment in annealing furnaces or the like. Fried. Krupp A.G. No. 504,650. May 31, 1929.

Construction of burners having an inner combustion chamber, according to Patent 479,867. No. 504,733. (Addition to No. 479,867.) Apr. 1, 1926.

Machine for casting difficultly fusible metals under pressure H. Barthel. No. 504,928. (Addition to No. 502,321.) Sept. 19, 1926.

Installation for cleaning castings. Maschinenfabrik Augsburg-Nürnberg A.G. No. 504,866. July 22, 1928.

Production of titanium oxide from titaniferous ores. I.G.Farbenindustrie A.G. No. 504,843. Sept. 2, 1928.

Electrolytic process for refining alloys of magnesium or of the alkaline earth metals. A. C. Jessup. No. 504,508. Sept. 12, 1926; in France Oct. 9, 1925.

Welded connection for wrought iron bell-and-spigot pipes. T. Behrens. No. 504,566. Feb. 25, 1925.

Means for removing fogs from electrolytic chromium baths. W. Steinhorst. No. 504,815. May 25, 1927.

Italian Patents

Subject of Invention, Patentee, Patent No. and Filing Date.

Fusion electrolytic process for obtaining aluminum. I. G. Farbenindustrie A.G. No. 266,556. Jan. 21, 1928; in Germany Jan. 21, 1927.

Moving mixing fore-hearth for obtaining refined, homogeneous cast iron. L. F. C. Girardet. No. 267,293. Feb. 27, 1928; in France Mar. 4, 1927. (French Patent No. 630,163.)

Process for making briquettes of iron ore concentrate. P. Gredt. No. 266,708. Feb. 9, 1928; in Germany Feb. 9, 1927.

Process for making alloys of iron and steel. T. R. Haglund. No. 266,725. Feb. 8, 1928; in Sweden Feb. 9, 1927.

Process for the simultaneous production of metals and alloys and highly refractory materials. T. R. Haglund. No. 266,838. Feb. 18, 1928.

Improved aluminum alloy. Rolls-Royce, Ltd. No. 267,161. Mar. 8, 1928; in Great Britain Mar. 17, 1927, in the names of H. C. Hall and T. F. Bradbury. (British Patent No. 281,912.)

New aluminum alloy and process for making it. P. Berthémy and H. De Montby. No. 267,192. (First addition to No. 249,542, filed May 4, 1926.) Jan. 5, 1928; in France Jan. 20, 1927.

Process for making pure iron and steel. H. J. Van Royen. No. 267,183. (First addition to No. 265,162, filed Dec. 14, 1927.) Dec. 15, 1927; in Germany Dec. 25, 1926.

Process for electric fusion welding. Allgemeine Elektricitäts Gesellschaft. No. 266,909. Feb. 14, 1928; in Germany Feb. 18, 1927.

Improvements to electric welding electrodes. Alloy Welding Processes, Ltd. No. 266,928. Feb. 16, 1928; in Great Britain Mar. 29, 1927, in the name of E. J. Clarke.

Connections for tilting melting furnaces. Demag A.G. No. 266,986. Feb. 27, 1928; in Germany Feb. 28, 1927.

Process for pressing bars of irregular cross-section. I. G. Farbenindustrie A.G. No. 266,736. Feb. 9, 1928; in Germany Feb. 9, 1928.

Improved draw press with interchangeable dies. A. Kreidler. No. 267,043. Mar. 1, 1928.

Process for preparing foundry sand for casting easily oxidizable metals, such as magnesium. Magnesium Industriel and British Maxium, Ltd. No. 267,167. Mar. 8, 1928.

Improvements in the production of blow-hole-free steel ingots. Midwest Metallurgical Corp. No. 266,610. Feb. 2, 1928.

Cooled roll for hot-rolling mills. C. Rötzel. No. 266,688. Feb. 11, 1928; in Germany Feb. 12, 1927.

Electric resistance welding machine for band saw blades. B. Sassi. No. 266,975. Feb. 20, 1928.

Apparatus for the reutilization and remelting of finely divided metals. J. Schmeller. No. 266,625. Mar. 23, 1928; in the U. S. Feb. 14, 1928. (U. S. Patent No. 1,659,445.)

Rapid preparation and maintenance of alkaline electrolytic baths for the oxidation and reduction of metals. Q. Sestini and B. Sestini. No. 267,084. Mar. 2, 1928.

Process for deoxidizing molten metals and alloys. Siemens & Halske A.G. No. 267,281. Feb. 28, 1928; in Germany Apr. 11, 1927.

Improvements to processes for the metallization and coating of substances with metal. G. A. I. Warren. No. 266,968. Feb. 29, 1928.

Process for protecting easily oxidizable metals having a base of magnesium, aluminum, calcium and the like. G. Michel. No. 267,222. (First addition to No. 247,034, filed Mar. 16, 1926.) Mar. 7, 1928; in France Mar. 12, 1927.

Method of forming the resistance-heating mass of an electric furnace. B. Chiaberge and O. Biglia. No. 267,100. Feb. 16, 1928; in Great Britain Nov. 18, 1927.

Improvements to electrodes for electrolysis. Soc. d'Electro-Chimie, d'Electro-Metallurgie et des Aciéries Electrique d'Ugine. No. 266,703. Feb. 8, 1928; in France Feb. 21, 1927.

Norwegian Patents

Subject of Invention, Patentee, Patent No. and Filing Date.

Process for making a metallic or alloy powder for the preparation of dental amalgams. E. W. Fischer and E. W. Jason Virgin. No. 48,180. Dec. 27, 1927.

Process and apparatus for casting molten metal under pressure. R. H. V. Christensen. No. 48,229. Feb. 5, 1929.

Process for coating metallic objects with metal. American Machine & Foundry Co. No. 48,283. July 7, 1928.

Elastic draw ring for wire-drawing machines. Drahtindustrie Peter Darmstadt & Co., G.m.b.H. No. 48,301. Sept. 21, 1928.

Hollow drill steel and process for making the same. Fagersta Bruks AB. No. 48,302. Nov. 29, 1928.

Process for coating the surfaces of iron or steel objects. Soc. Continentale Parker. No. 48,322. Dec. 21, 1928.

Swedish Patents

Subject of Invention, Patentee, Patent No. and Filing Date.

Process and apparatus for applying metallic coatings to metal objects. American Machine & Foundry Co. No. 69,962. Apr. 10, 1926.

Process for making alloys containing iron and chromium, molybdenum or uranium. R. W. Stimson. No. 70,081. Sept. 23, 1924.

Construction of ironless induction furnaces. Allmänna Svenska Elektriska AB. No. 70,087. Apr. 28, 1928.

Process for making longitudinal-seam tubing. V. Breitenbach. No. 70,110. Sept. 24, 1928; Priority date Sept. 23, 1927.

Machine for pressing metals or similar materiale. P. C. Christiansen. No. 70,111. Feb. 22, 1929; Priority date Mar. 1, 1928.

Process for removing nickel from zinc sulphate solutions. The Rhodesia Broken Hill Development Co., Ltd. No. 70,135. Nov. 27, 1926.

Process for making copper alloys. M. G. Corson. No. 70,136. (Addition to No. 68,922.) Aug. 26, 1927.

Electrolytic process for obtaining pure aluminum from crude aluminum, alloys and the like. Aluminium Industrie A.G. No. 70,171. Oct. 23, 1928; Priority date Feb. 4, 1928.

Process for forming metallic protective layers on metal. American Machine & Foundry Co. No. 70,177. July 5, 1928.